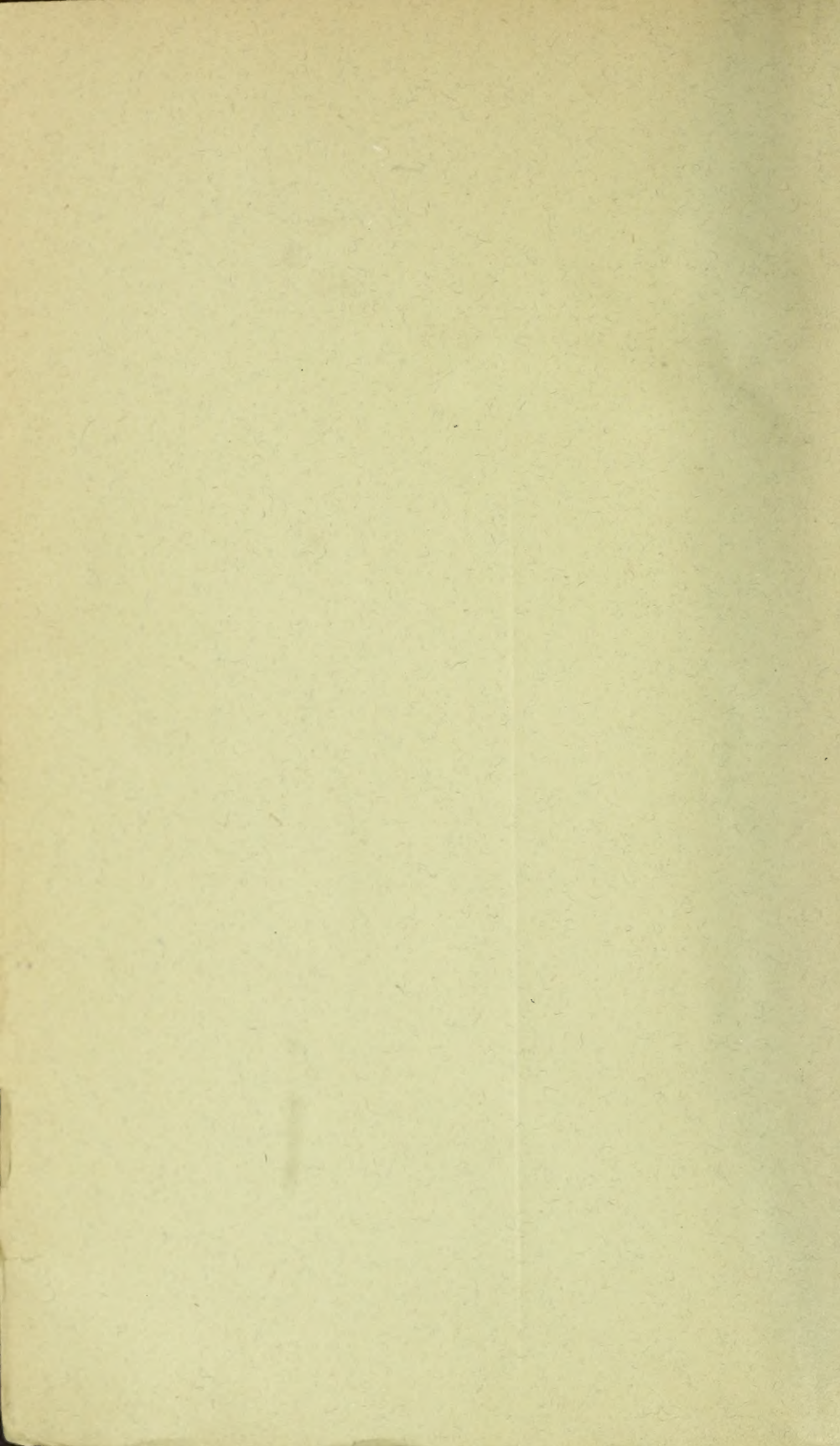


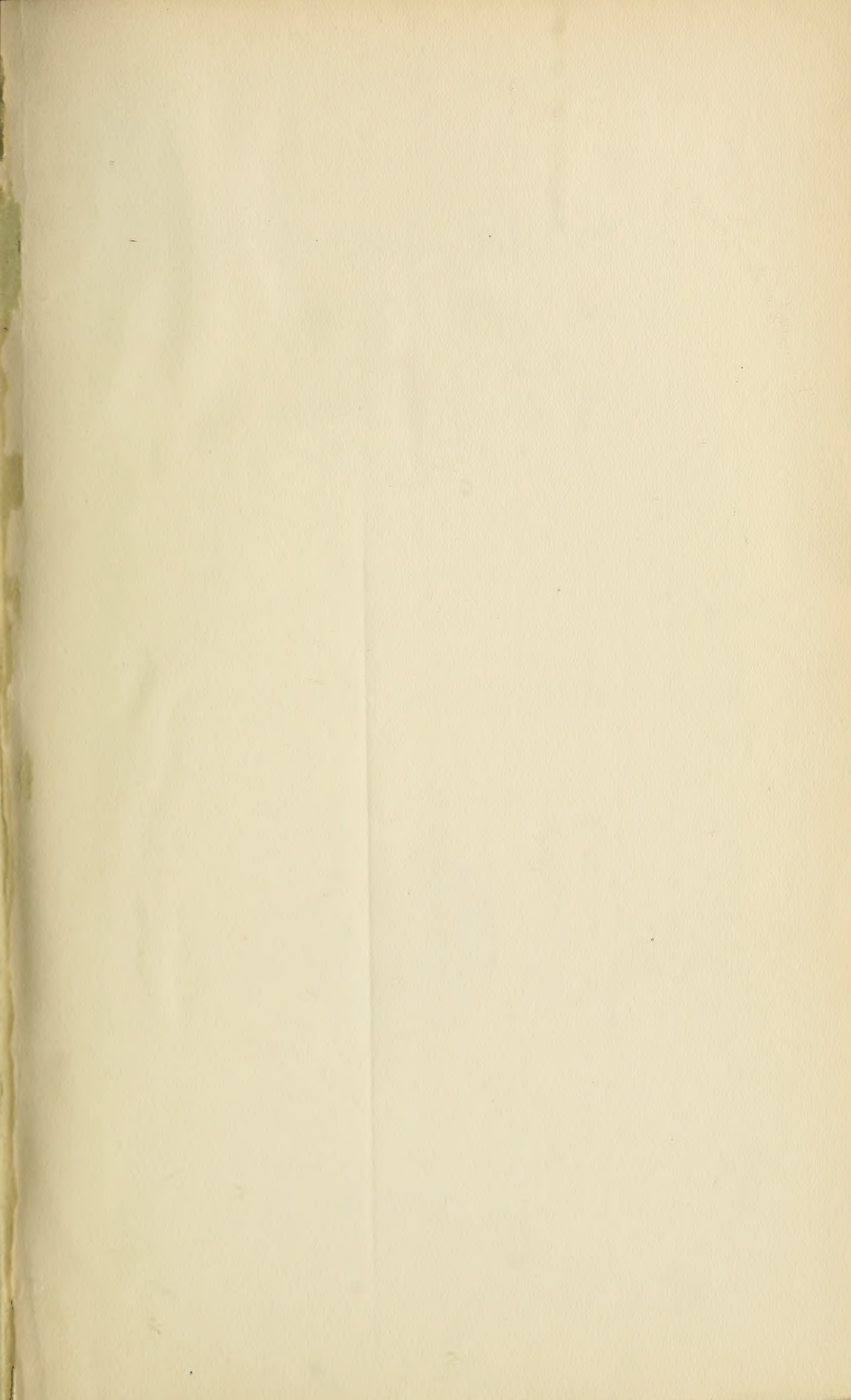


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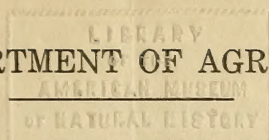
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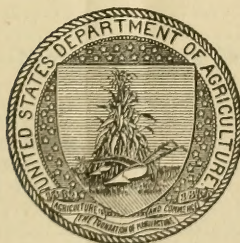


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GROUP CLASSIFICATION
AND VARIETAL DESCRIPTIONS OF
SOME AMERICAN POTATOES

By

WILLIAM STUART, Horticulturist

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(PROFESSIONAL PAPER.)

GROUP CLASSIFICATION AND VARIETAL DESCRIPTIONS OF SOME AMERICAN POTATOES.

By WILLIAM STUART.

Horticulturist, Horticultural and Pomological Investigations.

INTRODUCTION.

To those familiar with the present almost hopeless state of potato nomenclature it is apparent that there is a growing need for some simple and fairly reliable method by which the student and grower can recognize varieties well enough at least to place them in the family or group to which they belong. The classification of varieties into groups or families is admittedly the first step toward a satisfactory or intelligent study of the varieties themselves. The increasing necessity for such study is clearly demonstrated by the large number of old varieties offered to the public each year under the guise of new names. This practice has naturally led to much confusion, and the task of restoring order out of the present chaos is a difficult one.

EARLY EFFORTS AT CLASSIFICATION.

One of the earliest and most careful attempts to classify varieties into groups which has yet come to the writer's notice is that of Vilmorin,¹ who in 1882 and again in 1886 and 1902 published the results of many years' observations of a very complete collection of potato varieties. These varieties were grouped into 12 classes in 1886, and the 12 classes were further subdivided into 30 sections. In the 1902 edition only 9 classes were made, but these 9 classes were subdivided into 40 sections. The classification of the main groups is based on the color and shape of the tubers; that of the sections is based on the color, shape, and size of the tubers and the depth of the eyes, the color of the sprouts in the dark, and the color of the flowers.

¹ Vilmorin, C. P. H. L. de. *Catalogue Méthodique et Synonymique des Principales Variétés des Pommes de Terre*. Paris, 1882. Ed. 2, corr. et aug. de plus de 200 variétés, 51 p., Paris, 1886. Ed. 3, refond. et aug. de plus de six cents variétés, 87 p., Paris, 1902.

NOTE.—This bulletin is of value to plant breeders and potato specialists in all sections of the country.

The 9 classes are as follows:

- | | | |
|---------------------|----------------------------|-------------------------|
| (1) Yellow, round. | (4) Flesh colored, oblong. | (7) Rose or red, long. |
| (2) Yellow, oblong. | (5) Rose or red, round. | (8) Violet colored. |
| (3) Yellow, long. | (6) Rose or red, oblong. | (9) Streaked (mottled). |

The varieties included in class 1 are divided into ten sections, of which section 2 is perhaps a representative example.

SECTION 2.—Tubers yellow or white, round; flowers colored, often abundant; flesh white; sprouts violet, more or less colored.

One of the ablest attempts at group classification in this country is that of Kohler,¹ who, in March, 1909, published the first results of his studies on the classification of potato varieties. His grouping of the varieties is based upon the following points: (1) Characteristics of vines; (2) shape of tubers; (3) color of tubers.

Eleven groups were described in 1909, viz:

- | | |
|---------------------------|---------------------------|
| (1) Tuberosum group. | (7) Early Michigan group. |
| (2) Rural group. | (8) Milwaukee group. |
| (3) Endurance group. | (9) Russet group. |
| (4) Seedling B group. | (10) Ohio group. |
| (5) Green Mountain group. | (11) Early Market group. |
| (6) Carman group. | |

In a subsequent publication, April, 1910, Kohler retained the same number of groups, but submitted new names for four of them, his 1910 list being as follows:

- | | |
|----------------------------|---------------------------|
| (1) Tuberosum group. | (7) Green Mountain group. |
| (2) Wohltmann group. | (8) Michigan group. |
| (3) Rural group. | (9) Russet group. |
| (4) Endurance group. | (10) Ohio group. |
| (5) Factor group. | (11) Cobbler group. |
| (6) Sharp's Express group. | |

In many respects Kohler's grouping is satisfactory, but one might question the advisability of giving to any one group the name "Tuberosum." If all of the cultivated varieties are to be regarded as belonging to *Solanum tuberosum*, a group of only a few varieties can not be considered as exclusively entitled to such a designation. Exception might also be taken to three of the 1910 groups—Wohltmann, Factor, and Sharp's Express—which derive their group names from foreign varieties. It would seem desirable that the type variety should be one of American origin.

In 1912 Milward² mentions three groups as representing distinctive types. These he called the round-white, the long-white, and the Rose groups.

¹ Kohler, A. R. Potato experiments and studies at University farm. Minn. Agr. Exp. Sta. Bul. 114, p. 311-319, 1909.

Kohler, A. R. Potato experiments and studies at University farm in 1909. Minn. Agr. Exp. Sta. Bul. 118, p. 90-100, illus., 1910.

² Milward, J. G. Commercial varieties of potatoes for Wisconsin. Wis. Agr. Exp. Sta. Bul. 225, p. 7, 1912.

While this is an easy and simple classification to follow, particularly in the Rose group, it is impossible to make any close study of varietal relationship based on the shape of the tuber alone. Milward's classification is, of course, only intended to represent three standard market types of potatoes which are commonly recognized by the dealer when purchasing table stock. All of the varieties of the Rural and Green Mountain types fall into the round group, and these are generally known as Rurals. Those of the long-tuber type are generally known as Burbanks. The Rose group includes all varieties having elongated or ovoid tubers with flesh-colored or pink skin. In some respects this classification is most unfortunate, since it does not encourage the purification of varieties as regards mixture. Unscrupulous dealers have taken advantage of this situation and have disposed of such stock for seed purposes, thereby contributing in a large measure to the present nomenclatorial difficulties.¹

The object of this bulletin is to furnish a working plan which may be used in determining the group or family to which a variety belongs. It is hoped that in many cases it will also make possible the determination of the varieties themselves.

PROPOSED SYSTEM OF CLASSIFICATION.

In presenting the following classification key and group descriptions, no one realizes more clearly than does the writer that there is still much to be desired. It is hoped, however, that this classification will serve as a starting point upon which to base further studies. It is quite probable that the groups here presented will in many cases resolve themselves into one or more subgroups or sections which are based on finer distinctions than those given for the group as a whole. It is equally certain that some new groups will have to be made in order to include those varieties which do not at present seem to fit into any of the classes now proposed.

The value of studying varietal groups, rather than a collection of varieties as a whole, can not be too strongly emphasized. When the varieties falling into such groups are planted in adjacent rows the comparative differences, as well as similarities, are more easily noted. The recognition of old varieties under new names is almost certain

¹ Since the preparation of this manuscript, the Agricultural Extension Department of the Iowa State College of Agriculture has published Extension Bulletin No. 20, entitled "Identification of Potato Varieties." The author of this bulletin, C. L. Fitch, makes the following statement: "The identification of varieties of potatoes will be considered under three heads: 1. The varieties of interest to Iowa growers and merchants, pp. 3-4. 2. Tubers described and tuber parts named; the influence of conditions on shape and color, pp. 5-14. 3. Varieties described and identified by the tuber form and color markings, pp. 14-32."

Under part 3 the author discusses seven groups, or classes, as follows: Rural, Early Ohio, Irish Cobbler, Green Mountain, Burbank, Peerless or Pearl, and Bliss Triumph. Each group is well illustrated by photographs showing the range of variation in shape of the tubers. Taken as a whole, the bulletin is an exceedingly interesting one and should prove of considerable value in the study of potato varieties.

to result from such a study and should tend to discourage the present practice of some of the seedsmen who manufacture new varieties out of old ones.

CLASSIFICATION KEY.¹

Group 1.—COBBLER.

Tubers: Roundish; skin creamy white.

Sprouts: Base, leaf scales, and tips slightly or distinctly tinged with reddish violet or magenta. In many cases the color is absent.

Flowers: Light rose-purple; under intense heat may be almost white.

Group 2.—TRIUMPH.

Tubers: Roundish; skin creamy white, with more or less numerous splashes of red, or carmine, or solid red; maturing very early.

Sprouts: Base, leaf scales, and tips more or less deeply suffused with reddish violet.

Flowers: Very light rose-purple.

Group 3.—EARLY MICHIGAN.

Tubers: Oblong or elongate-flattened; skin white or creamy white, occasionally suffused with pink around bud-eye cluster in Early Albino.

Sprouts: Base light rose-purple; tips creamy white or light rose-purple.

Flowers: White.

Group 4.—ROSE.

Tubers: Roundish oblong to elongate-flattened or spindle-shape flattened; skin flesh colored or pink, or (in the case of the White Rose) white.

Sprouts: Base and internodes creamy white to deep rose-lilac; leaf scales and tips cream to rose-lilac.

Flowers: White in sections 1 and 2; rose-lilac in section 3.

Group 5.—EARLY OHIO.

Tubers: Round, oblong, or ovoid; skin flesh colored or light pink, with numerous small, raised, russet dots.

Sprouts: Base, leaf scales, and tips more or less deeply suffused with carmine-lilac to violet-lilac or magenta.

Flowers: White.

Group 6.—HEBRON.

Tubers: Elongated, somewhat flattened, sometimes spindle shaped; skin creamy white, more or less clouded with flesh color or light pink.

Sprouts: Base creamy white to light lilac; leaf scales and tips pure mauve to magenta, but color sometimes absent.

Flowers: White.

Group 7.—BURBANK.

Tubers: Long, cylindrical to somewhat flattened, inclined to be slightly spindle shaped; skin white to light creamy white, smooth and glistening, or deep russet in the case of section 2.

Sprouts: Base creamy white or faintly tinged with magenta; leaf scales and tips usually lightly tinged with magenta.

Flowers: White.

Group 8.—GREEN MOUNTAIN.

Tubers: Moderately to distinctly oblong, usually broad, flattened; skin a dull creamy or light russet color, frequently having russet-brown splashes toward the seed end.

Sprouts: Section 1—base, leaf scales, and tips creamy white; section 2—base usually white, occasionally tinged with magenta; leaf scales and tips tinged with lilac to magenta.

Flowers: White.

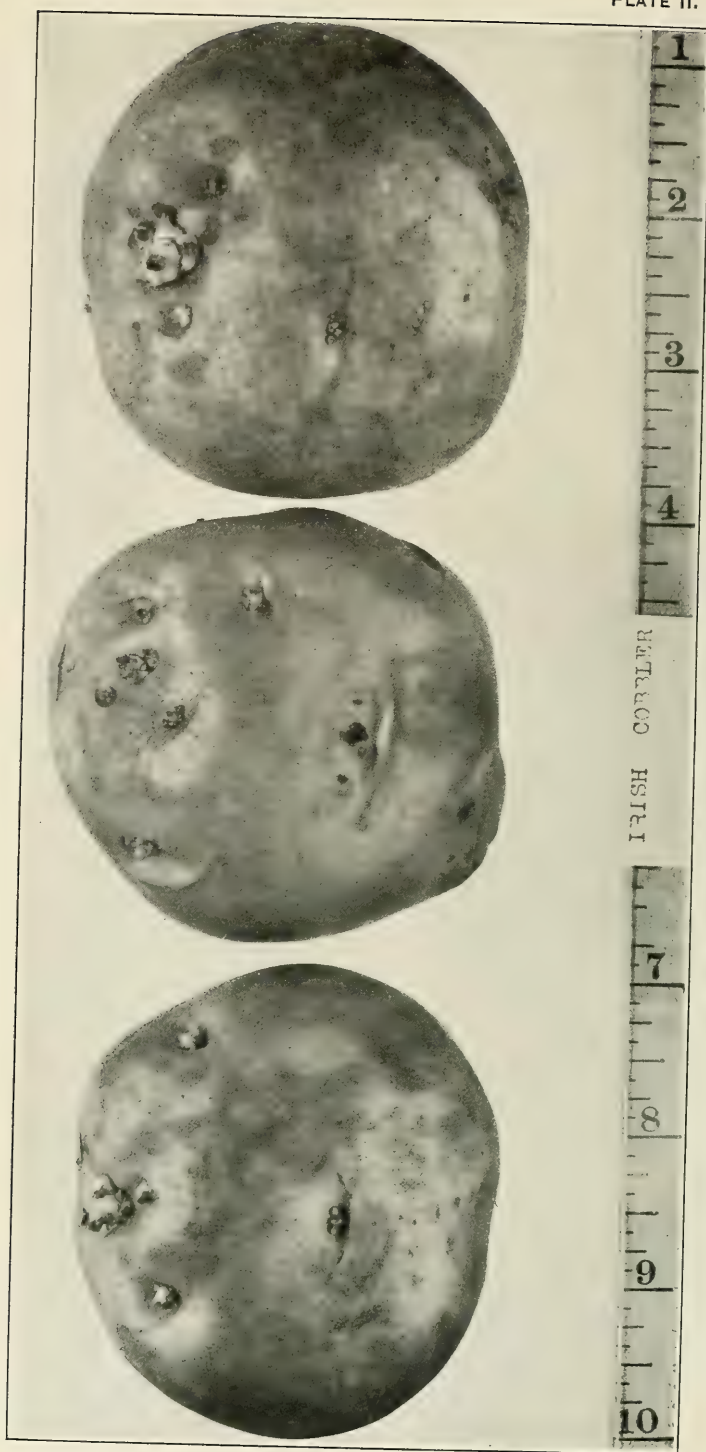
¹ The color values are based upon the chart published by the French Chrysanthemum Society, Paris, 1905.



FIG. 1.—FOUR VIEWS OF IRISH COBBLER POTATOES.



FIG. 2.—FOUR VIEWS OF EXTRA-EARLY EUREKA POTATOES.
POTATOES BELONGING TO GROUP 1.



THREE IRISH COBBLER POTATOES, GROUP 1.

A desirable type and ideal seed size.



TWO IRISH COBBLER POTATOES, GROUP 1.

The tuber on the left, while desirable in shape, has eyes that are too deep. The tuber on the right shows a tendency to run out, as evidenced by the pointed seed end.



FIG. 1.—FOUR VIEWS OF QUICK LUNCH POTATOES.



FIG. 2.—FOUR VIEWS OF TRIUMPH (BLISS'S) POTATOES.

POTATOES BELONGING TO GROUP 2.



THREE TYPICAL EARLY MICHIGAN POTATOES, GROUP 3.



FIG. 1.—FOUR VIEWS OF EARLY ROSE POTATOES GROWN IN MAINE.

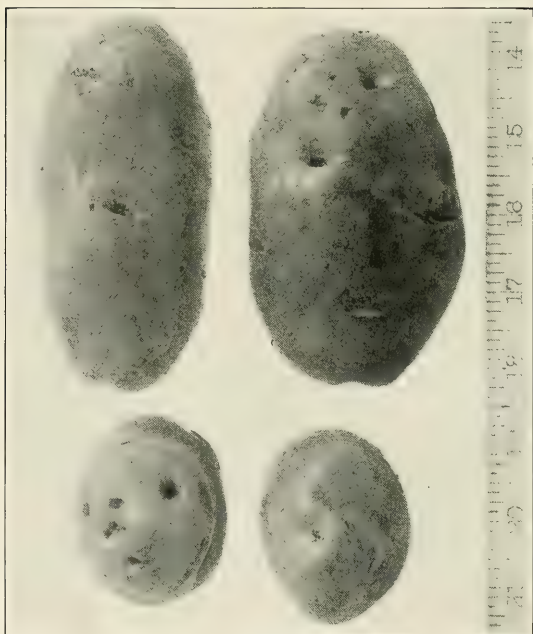


FIG. 2.—FOUR VIEWS OF EARLY ROSE POTATOES GROWN IN MINNESOTA.

POTATOES BELONGING TO GROUP 4,
SECTION 1.

Group 9.—RURAL.

Tubers: Broadly round-flattened to short oblong, or distinctly oblong-flattened; skin creamy white, or deep russet in the case of section 20.

Sprouts: Base dull white; leaf scales and tips violet-purple to pansy violet.

Flowers: Central portion of corolla deep violet, with the purple growing lighter toward the outer portion; five points of corolla white, or nearly so.

Group 10.—PEARL.

Tubers: Round-flattened to heart-shape flattened, usually heavily shouldered; skin dull white, dull russet, or brownish white in section 1 or a deep bluish purple in section 2.

Sprouts: Section 1—base, leaf scales, and tips usually faintly tinged with lilac; section 2—base, leaf scales, and tips vinous mauve.

Flowers: White.

Group 11.—PEACHBLOW.

Tubers: Round to round-flattened or round-oblong; skin creamy white, splashed with crimson or solid pink; eyes usually bright carmine. Includes some early-maturing varieties.

Sprouts: Base, leaf scales, and tips more or less suffused with reddish violet.

Flowers: Purple.

In deciding upon the name by which each group shall be known an attempt has been made to select that of the variety which seems most nearly to represent the group as a whole and which, at the same time, is most widely known.

In the group descriptions which follow an effort has been made to give the general characteristics of the vines and tubers for the group as a whole. It is realized, however, that in all probability the descriptions more closely approach the characters of the variety furnishing the group name.

All descriptions of the color of the sprouts are based on the observation of tubers sprouted in a dark chamber.

1.—COBBLER GROUP.

The Cobbler group represents a class of early-maturing potatoes. The Irish Cobbler is by far the most extensively grown variety of this group, being almost universally raised for an early crop in the Norfolk and Eastern Shore trucking districts of Virginia and Maryland. It is also rather extensively grown in other trucking centers and is gradually supplanting such varieties as the Triumph and the Spaulding No. 4. Large quantities of Irish Cobblers are also grown in northern Maine to supply seed for southern truck growers. Plates I, II, and III illustrate different types of potatoes belonging to group 1.

Description.—Matures early. Vines medium to above medium in size, with somewhat spreading habit of growth. Stems dark green, stocky, and rather short jointed. Leaves large, flat, more or less flaccid, and a medium dark green. Flowers numerous, rather large, light purple or rose-lilac; under intense heat the color may be practically unexpressed. Tubers roundish with blunt ends, the stem end often being notched rather deeply and giving a shouldered appearance to the tuber (Pl. I, figs. 1 and 2). Eyes medium in number, varying from shallow to rather deep, particularly in the

bud-eye cluster (Pls. II and III). Skin smooth and of a light, creamy white color. Sprouts short and rather stubby, varying in color at the base from a very faint reddish violet or magenta to a perceptible coloration; the tips and leaf scales are usually tinged with the same color. Occasionally the color seems to be almost, if not entirely, absent.

The following varieties belong to this group and are, to all intents and purposes, identical:

Early Dixie.	Extra-Early Eureka (Pl. I, fig. 2).
Early Eureka.	Flourball.
Early Petoskey.	Irish Cobbler (Pl. I, fig. 1; Pls. II
Early Standard.	and III).
Early Vicktor.	Potentate.

2.—TRIUMPH GROUP.

The Triumph group is composed of a few very early varieties having roundish tubers and a dwarf habit of growth. Only one member of this group, the Triumph, can be regarded as having any considerable commercial importance. Both the Triumph and the Quick Lunch potatoes are illustrated in Plate IV.

Description.—Ripens very early, but the yield is usually low. Vines dwarfed and fairly compact, not much branched. Stems short, stocky, dark green. Leaves medium large and dark green. Flowers purple or rose-lilac. Tubers round with blunt to obtuse ends, slightly to distinctly shouldered (Pl. IV, fig. 1). Eyes medium in number and depth; bud-eye cluster generally deeply set. Skin creamy white, occasionally with pink eyes or splashes (as in the White Triumph), with few or many splashes of crimson (as in the Quick Lunch and Noroton Beauty), or solid red, or occasionally splashed with carmine (as in the Triumph). Flesh a creamy white. Sprouts have base, leaf scales, and tips more or less deeply diffused with reddish violet.

The varieties which seem to belong to this group are the following:

Honeye Rose. ¹	Triumph (Bliss's) (Pl. IV, fig. 2).
Noroton Beauty.	White Triumph.
Quick Lunch (Pl. IV, fig. 1).	

3.—EARLY MICHIGAN GROUP.

This group has been provided for the purpose of accommodating certain early white-skinned varieties which, owing to their habit of growth, color of flowers, and color and shape of tubers, could not be included in any of the other groups. Thus far the study which has been given to the possible members of this group has been insufficient to permit a description which would fairly represent them. Plate V shows three typical Early Michigan potatoes.

Description.—Matures early. Vines of medium size, resembling those of the Early Ohio group. Flowers white. Tubers oblong-flattened to elongate-flattened or ovoid. Eyes numerous. Skin white or creamy white or, in the case of the Early Albino, occasionally suffused with pink around the bud-eye cluster. Sprouts light rose-purple at the base, with the scales and tips creamy white or tinged with light rose-purple.

¹ The first three varieties are considered identical.

The varieties in this group which have been studied are the Early Albino, Early Michigan (Pl. V), and Early Puritan.

Further investigation will doubtless result in the inclusion of a number of other varieties.

4.—ROSE GROUP.

In point of numbers the Rose group is one of the largest, if not the largest, group under this classification. With the exception of the Extra-Early White Rose, all of the varieties in this group have pink-skinned tubers, and all save the Late Rose may be classed as early-maturing varieties.

In order to accommodate certain varieties which apparently belong to this group, but which differ either in shape of tubers, color of sprouts, or flowers, it has been found necessary to make three sections, in the first of which are included the true Early Rose types. The vine description of the Early Rose in section 1 will serve reasonably well for all. Plates VI, VII, and VIII illustrate the different varieties belonging, respectively, to sections 1, 2, and 3.

Description.—Section 1: Vines of medium height, with stout, rather erect, dark-green stems and medium to large leaves. Flowers rather abundant, white. Tubers elongated or oblong, usually flattish at the center and tapering gradually toward each end; stem and seed end rather blunt. In the North, tubers tend to become shorter, thicker, and more nearly round. (Pl. VI, figs. 1 and 2.) Eyes numerous, shallow to medium in depth, but sharply marked; sometimes protuberant. Skin smooth and, except in the Extra-Early White Rose, of a rather deeper shade of flesh color or pink than the Early Ohio. Flesh creamy white, sometimes streaked with red. Sprouts rather long, medium thick, the base not much enlarged (Pl. IX, fig. 1) and usually clearly tinted with rose-lilac; leaf scales and tips creamy white or tinged with rose-lilac.

The following varieties are thought to belong to section 1:

Clark's No. 1.	Extra-Early Fillbasket.
Early Durham.	Extra-Early Vermont.
Early Fortune.	Extra-Early White Rose.
Early Maine.	Houlton Rose.
Early Norther.	Late Rose.
Early Rose (Pl. VI).	Northern Beauty.
Early Roser.	Rochester Rose.
Early Thoroughbred.	Somers' Extra Early.
Early Vermont.	Thorburn.
Early Walters.	

Section 2: Vines larger and more luxuriant than those of section 1. Flowers white. Tubers broad-roundish to short-oblong, flattened (Pl. VII): Eyes not very numerous and rather shallow. Skin slightly deeper colored than that of the Early Rose. Sprouts shorter and thicker and usually considerably enlarged at the base; color of sprouts mauve; leaf scales and tips deep mauve or magenta.

The varieties classed under section 2 are the Manistee (Early and Improved) and Spaulding No. 4 (Pl. VII).

Section 3: Vines quite similar to those of section 1. Flowers purple or rose-lilac. Tubers oblong, rather broad and thick, more or less flattened, large (Pl. VIII). Eyes

numerous, usually deeply colored. Skin much deeper pink than that of the Early Rose. Sprouts short, stubby, and showing about as much color as those in section 2.

The varieties now thought to belong to section 3 follow.

Crine's Lightning.	New Ideal (Pl. VIII).
Extra Early Red Rose.	New Scotch Rose.
Jones Pink-Eyed Seedling.	Old Early Rose (Pl. VIII).
Lee's Favorite.	Seneca Beauty.
Livingston.	

5.—EARLY OHIO GROUP.

This group is relatively more important than that of the Rose, owing to the fact that the Early Ohio variety is much more extensively grown. In the potato-growing regions of the Middle West the Early Ohio is still one of the leading commercial varieties. This is particularly true in the Red River Valley of Minnesota and North Dakota and in the valley of the Kansas (Kaw) River; it is equally true in other less well-known localities. While in many respects the varieties in this group are very similar to those of the Rose group, there are certain distinguishing characters which make their recognition comparatively easy. Plate IX, figure 2, and Plate X show different views of the Early Ohio.

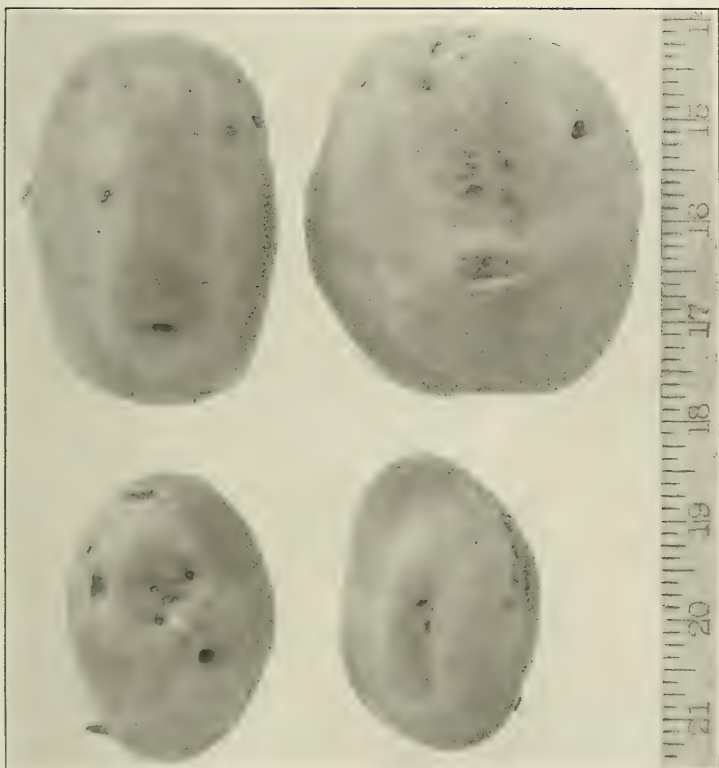
Description.—Vines very similar to those of the Early Rose in habit of growth, character of foliage, and color of flowers; they mature a little earlier, however. Flowers white. Tubers round-oblong with full, rounded seed and stem ends (Pl. X). Eyes numerous, rather shallow, but strong, sometimes protuberant. Skin or flesh light pink, except in the case of the White Ohio, with deeper color around the eyes, particularly around the bud-eye cluster. Surface of skin more or less numerously dotted with small corky dots (lenticels). (Pl. X, tuber 157.) These dots either do not occur at all or are relatively inconspicuous on the Rose varieties. Sprouts short, much enlarged at the base (Pl. IX, fig. 2), color varying from carmine-violet to violet-lilac or magenta-lilac.

Apparently most of the varietal members of this group are simply renamed Early Ohios; at least this statement is true of the first four varieties in the following list:

Early Ohio (Pl. X).	Early Acme.
Early Market.	Early Six Weeks.
Prize Early Dakota (Pl. X).	Late Ohio.
Ratekin's Red River Special.	White Ohio.

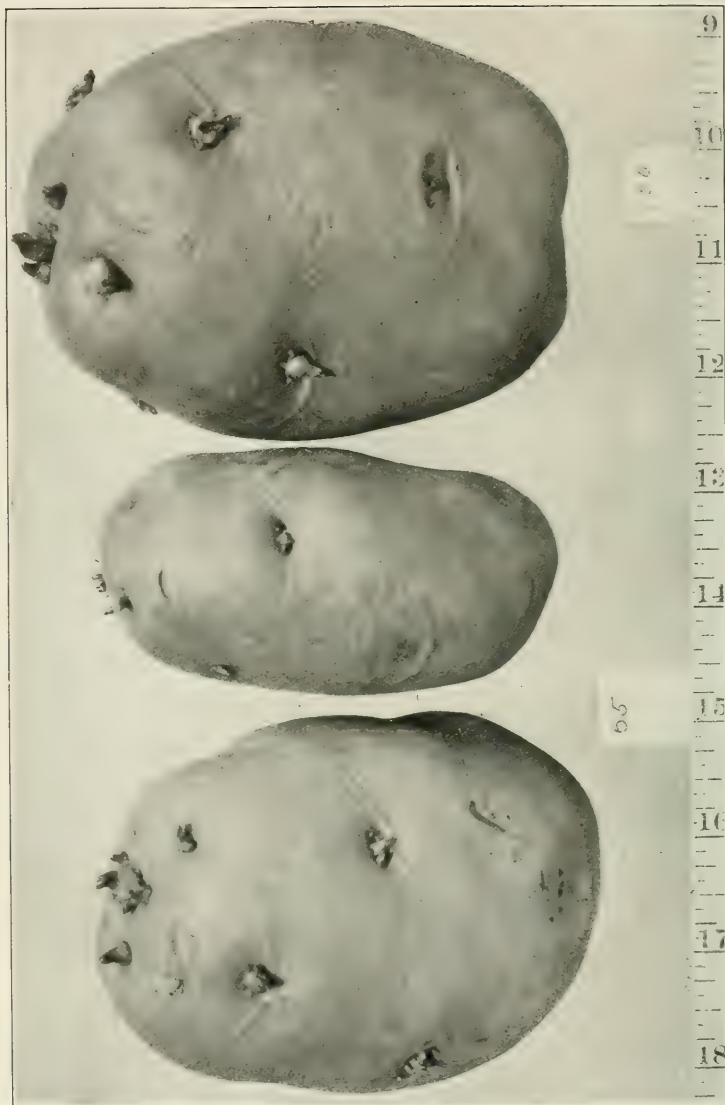
6.—HEBRON GROUP.

The varieties in the Hebron group are chiefly distinguished from those in the Rose group by the color of their tubers. Most of them are early-maturing varieties. The Early and Late Beauties of Hebron were rather extensively grown a quarter of a century or more ago, but are now seldom grown commercially. Their decadence has been largely due to the fact that they are very susceptible to the late-blight. Another factor which may have had some influence in this direction is the shape of the tuber, which is undesirably long.



POTATOES BELONGING TO GROUP 4, SECTION 2.

Four views of Spaulding No. 4, (Rose No. 4).



POTATOES BELONGING TO GROUP 4, SECTION 3.

Tubers 65 show the relative breadth and thickness of the Old Early Rose; tuber 106, the relative breadth of the New Ideal.

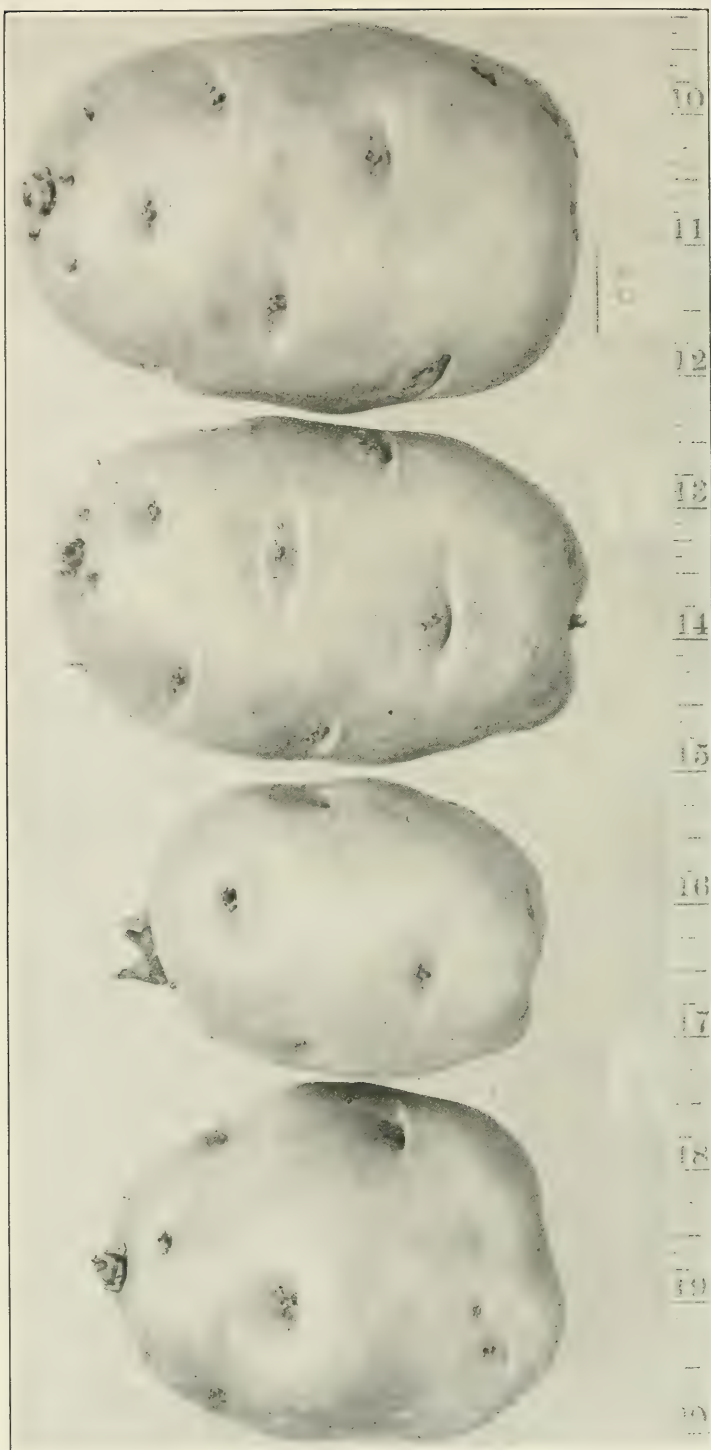


FIG. 1.—POTATOES BELONGING TO GROUP 4.



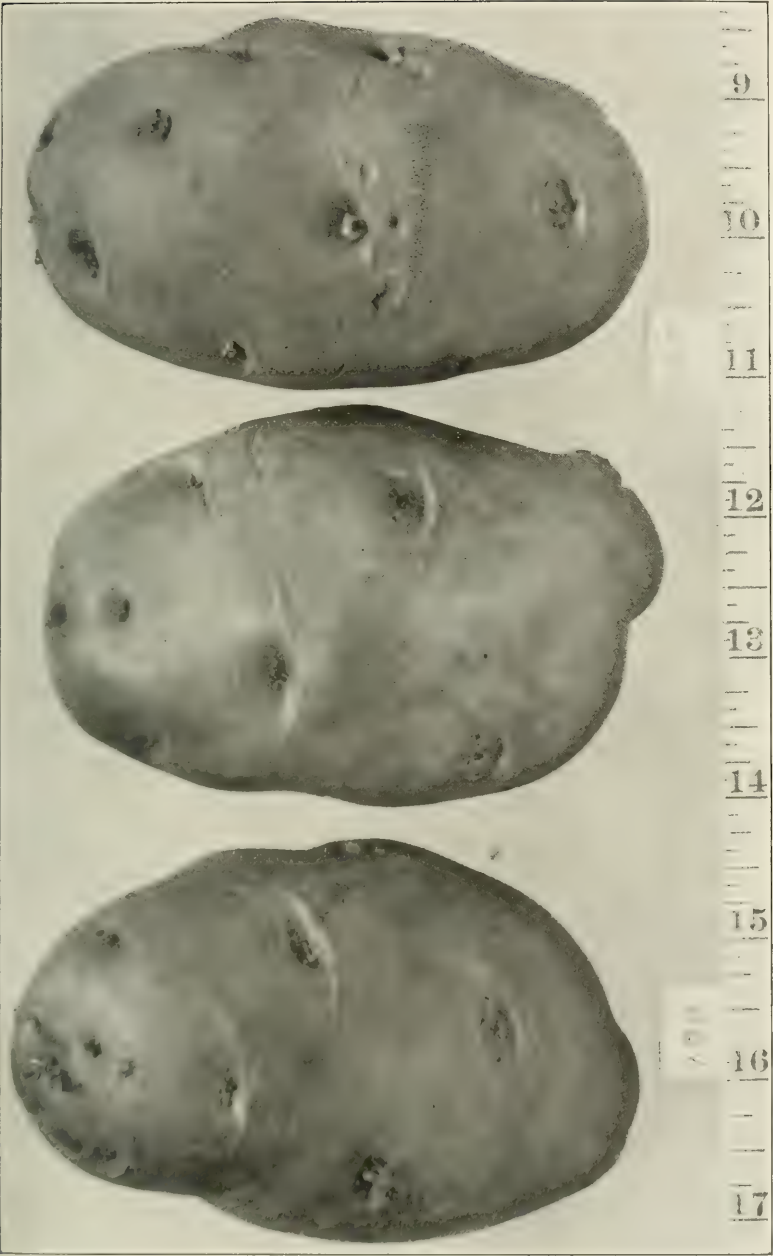
FIG. 2.—POTATOES BELONGING TO GROUP 5.

CHARACTER OF POTATO SPROUTS IN THE LIGHT.

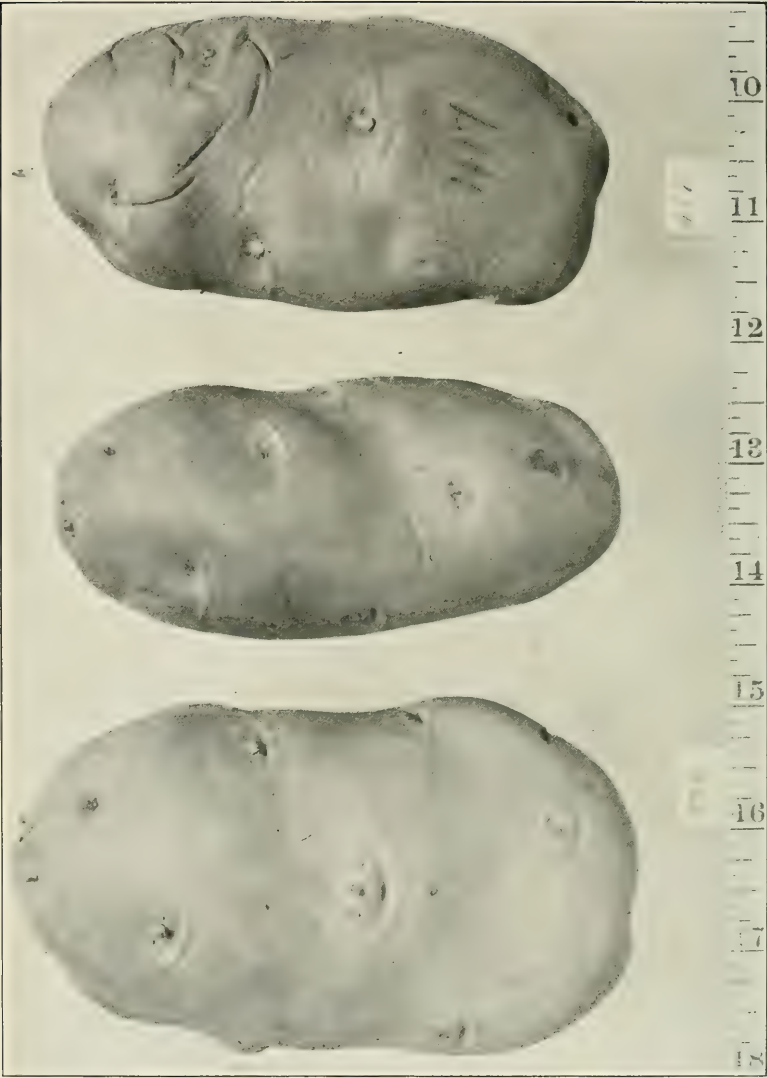


POTATOES BELONGING TO GROUP 5.

Tubers 152 and 157 are Early Ohio; tuber 169 is Prize Early Dakota. Nos. 157 and 169 represent a good type of Early Ohio, although the latter bears a different name.



POTATOES BELONGING TO GROUP 6.
Tuber 188 is Late Beauty of Hebron; tubers 195, Columbus.



THREE POTATOES BELONGING TO GROUP 7, SECTION 1.

Tubers 392 show the relative breadth and thickness of Pride of Mulnomah; tuber 417 shows the breadth of White Beauty.



FOUR POTATOES BELONGING TO GROUP 7.

Tubers 339 show the relative breadth and thickness of Burbank's Seedling (section 1); tubers 558, of Russet Burbank (section 2).

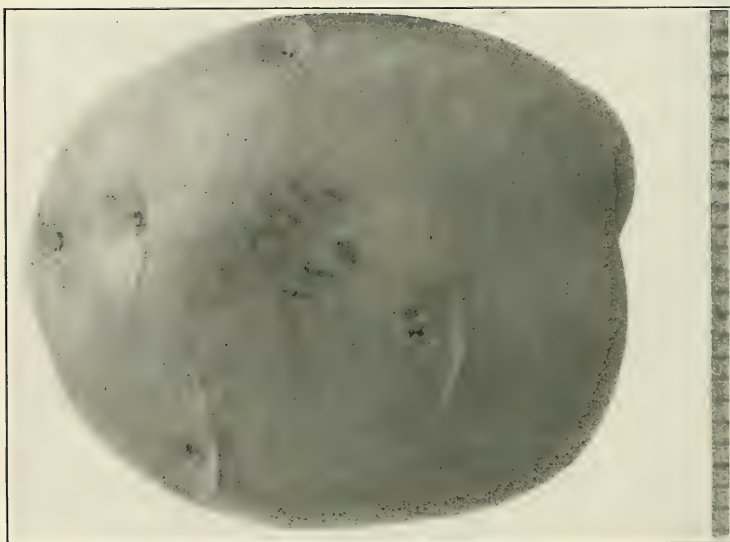


FIG. 1.—SHORT-OBLONG OR BROADLY ROUNDISH FLATTENED TYPE OF GREEN MOUNTAIN POTATO.

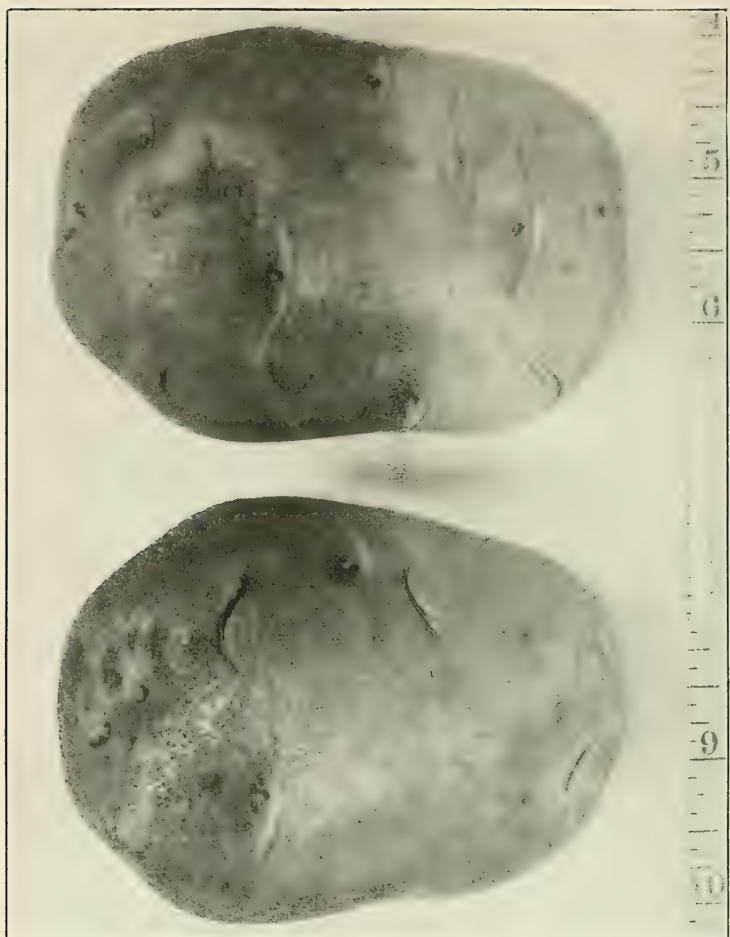


FIG. 2.—DISTINCTLY OBLONG-FLATTENED AND MORE CHARACTERISTIC TYPE OF GREEN MOUNTAIN POTATO.

THREE POTATOES BELONGING TO GROUP 8, SECTION 1.

Description.—Varieties of this group mature medium early, except in the case of the Late Beauty of Hebron. Vines very similar to those of the Early Rose. Flowers white. Tubers elongated, somewhat flattened, with rather blunt ends, occasionally spindle shaped (Pl. XI). Eyes numerous, medium deep. Skin creamy white, more or less clouded with flesh color or light pink. Sprouts very similar to those in section 1 of the Early Rose group, but with rather less color.

The varieties in the Department of Agriculture collection which are thought to belong to this group follow.

Columbus (Pl. XI).	Junior Pride.
Country Gentleman.	Late Beauty of Hebron (Pl. XI).
Crown Jewel.	Milwaukee.
Early Beauty of Hebron.	New Queen.
Early Bovee.	Quick Crop.
Gem of Aroostook.	Star of the East.
Harbinger.	Vigorosa.
Improved Beauty of Hebron.	White Elephant.

7.—BURBANK GROUP.

While the Burbank group is relatively small, it is by no means unimportant. The potatoes in this group are very much more widely grown in the West than in the East, their production being probably most concentrated on the delta lands of the Sacramento and San Joaquin Rivers, near Stockton, Cal. The varieties constituting this group all produce long, cylindrical, white or russet tubers. It has not been thought advisable to attempt to make two groups, one white and one russet, because in all other respects the potatoes appear to be very similar. To accommodate these two classes of tubers the group has been divided into two sections, section 1 including the white-skinned types and section 2 the russet-skinned ones.

Description.—Vines bushy and medium large. Stems light to medium green, branched, and spreading. Leaves abundant and medium in size, medium green in color. Flowers white.

Section 1: Tubers long, cylindrical, or slightly flattened in shape (Pls. XII and XIII), inclined to be prongy when climatic conditions are abnormal. Eyes numerous and well distributed, rather shallow, occasionally protuberant. Skin white to dull white, smooth to glistening. Sprouts, base creamy white or faintly tinged with magenta, leaf scales and tips usually lightly tinged with magenta.

Section 2: Tubers have russet skin, heavily netted or reticulated (Pl. XIII, tuber 558). In all other respects these are very similar to those of section 1, except possibly that the tubers of Cambridge Russet and Scabproof are slightly more flattened.

The varieties listed below seem to belong to this group.

Section 1:	Section 2:
Burbank, or Burbank's Seedling (Pl. XIII).	California Russet.
Money-Maker.	Cambridge Russet.
Pride of Multnomah (Pl. XII).	Olds's Golden Russet.
White Beauty (Pl. XII).	New Wonderful.
White Chief.	Russet Burbank (Pl. XIII).
	Scabproof.

8.—GREEN MOUNTAIN GROUP.

The members of the Green Mountain group may be said to share honors with those of the Rural in their commercial importance. They seem to be particularly well adapted to northern latitudes where the rainfall is abundant and the temperature is not excessively high. As a rule, they do not succeed as well in localities where they are subjected to unfavorable conditions of growth during the time they are forming tubers as do the members of the Rural group. The varieties in this group are divided into two sections, according to whether they have white or slightly colored sprouts.

Description.—Vines large, strong, healthy, and well branched. Stems nearly upright in early stages of growth, but gradually assuming a spreading habit toward the latter end of the season. Flowers white, abundant, rarely producing seed balls except under very favorable climatic and soil conditions. Tubers broadly roundish flattened to distinctly oblong-flattened; ends usually blunt, especially the seed end (Pls. XIV and XV). Eyes medium in number, rather shallow, with strong bud-eye cluster. Skin dull creamy white, more or less netted, frequently with russet-colored splashes toward the seed end. Sprouts rather short and stubby. In section 1 they are white. Those in section 2, with the exception of Twentieth Century and Late Puritan, are mostly without color at the base, while the leaf scales and tips are usually faintly or distinctly tinged with lilac or magenta.

The following varieties are believed to belong to the white-sprout division, section 1:

Bethel Beauty.	Gurney's White Harvest (Pl. XV).
Blightless Wonder.	Keystone.
Carman No. 1.	Late Blightless.
Clyde.	Long Island Wonder.
Delaware.	Norcross.
Empire State.	Pride.
Farmer.	Snow.
Freeman.	State of Maine.
Gold Coin (Pl. XV).	Uncle Sam.
Green Mountain (Pl. XIV).	White Mountain.
Green Mountain, Jr.	

The colored-sprout division, listed as section 2, consists of the Charles Downing, Idaho Rural, and Rustproof varieties.

9.—RURAL GROUP.

The Rural group includes a large number of strong-growing, late-maturing varieties. Collectively they are now commonly referred to by New York State growers as "blue-sprout" potatoes. This term distinguishes them from the "white-sprout" varieties belonging to the Green Mountain group. The varieties of the Rural group seem to be admirably adapted to northern and western New York and to certain sections of Michigan and Wisconsin, and they can also be successfully grown in the New England States. The tubers keep well in storage and are slow to germinate in the spring. The vines develop slowly at first, but as the season advances they branch rather

freely and develop reasonably large plants. Tuber formation seems also to be delayed, but when the proper growing conditions prevail in the latter part of the season a crop is developed very rapidly. As a group, the tubers are of desirable shape, attractive color, and good table quality, and the vines are fairly resistant to drought and to diseases other than the late-blight.

In order to include russet-skinned varieties possessing characters practically identical in all other respects with those of the white-skinned class, it has been thought desirable, as in the case of the Burbank group, to make two sections. Inasmuch as the vine and tuber characteristics, save for the color of the skin, are alike for the two sections, one description serves equally well for both.

Description.—Vines medium large. Primary stem upright, long jointed, and rather sparsely covered with foliage; lateral branches more or less decumbent, giving the plant a straggly appearance. Stems more or less distinctly streaked with dark purple. Leaves rather small, dark green, more or less rugose or crumpled, and leathery to the touch. Flowers medium, abundant, and of fair size; the central portion of the corolla is a deep violet-purple, which gradually shades into a lighter tone toward the periphery. The color is practically absent on the upper side of the five points of the corolla. Tubers round-flattened to broadly roundish oblong-flattened or distinctly oblong (Pl. XVI.). Eyes few, very shallow, bud-eye cluster strong and frequently depressed. Skin creamy white and occasionally netted in the varieties of section 1, while in those varieties belonging to section 2 it is a deep-russet color and much netted. Sprouts short, base enlarged, dull white; leaf scales and tips medium to deep purple or pansy violet.

The varieties which have been recognized as belonging to section 1 of this group appear in many cases to be old ones under new names; as, for example, Late Vicktor, Lily White, No. 9, Noxall, Ohio Wonder, Prosperity, Rhind's Hybrid, and White Giant. These varieties are all considered to be practically identical with the Rural New Yorker No. 2.

The following varieties are classified under sections 1 and 2:

Section 1:	Section 1—Continued.
Arcadia.	Prosperity.
Carman No. 3 (Pl. XVI, fig. 2).	Rhind's Hybrid.
Great Divide.	Rural New Yorker No. 2 (Pl.
Jackson White.	XVI, fig. 1).
Late Vicktor.	Sir Walter Raleigh.
Lily White.	White Giant.
Million Dollar	White Swan.
Noxall.	Section 2:
No. 9.	Late Petoskey (Rural Russet).
Ohio Wonder.	Russet (Dibble's).
Pearless (Bressee's No. 6) or Boston.	

10.—PEARL GROUP.

So far as the writer's studies are concerned, only three varieties can be assigned to the Pearl group. These are the Pearl, the People's, and the Blue Victor. In Colorado, Idaho, and adjoining States

there are rather extensive commercial plantings of the first two varieties. The Blue Victor is grown only as a novelty or for family use at the present time. It matures somewhat later than either the Pearl or the People's.

Owing to the pronounced variation in the color of the tubers and, to a lesser extent, in the color of the stems between the Blue Victor and the other two varieties, it has been deemed advisable to divide the group into two sections.

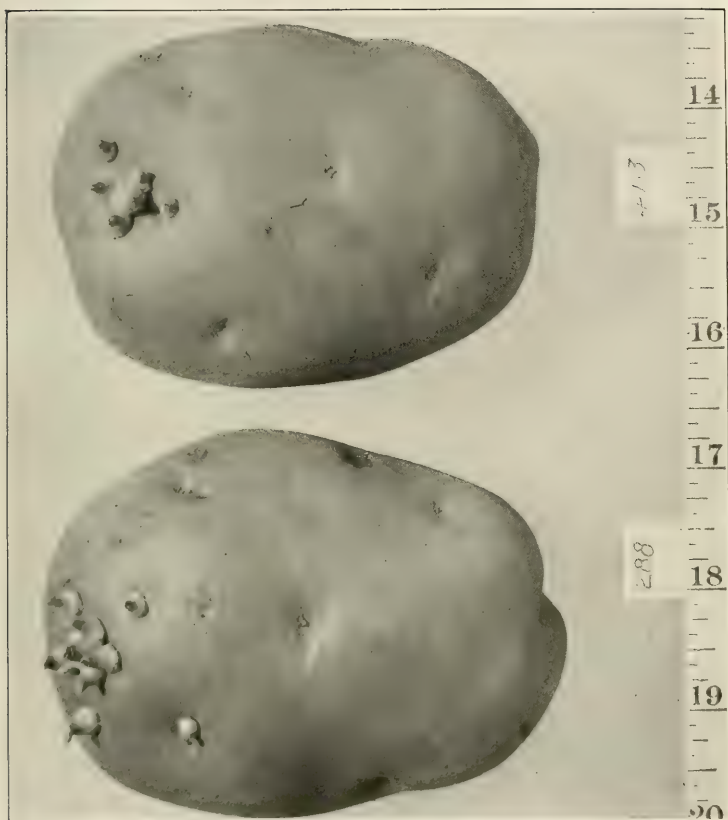
Description.—Vines medium to large, strong, healthy and as a rule well branched; stems dark green (in section 2 streaked with purple), more or less upright in early stages of growth, but gradually assuming a somewhat decumbent position as the vine approaches maturity. According to Fitch,¹ the main stem of the Pearl should assume a more or less horizontal position and the lateral branches an upright position. Leaves medium to large in size, rather flat, somewhat rugose, and approaching dark green when well grown. Flowers white. Tubers medium to large, solid fleshed and heavy, round-flattened to heart-shape flattened, usually heavily shouldered and broader at the stem end. Under unfavorable conditions the tubers seem to have a decided tendency to elongate and become less flattened. Eyes rather shallow, sometimes protuberant, or in off-type specimens inclined to be deep with heavy eyebrows. The bud-eye cluster in a normal specimen is shallow, while in an abnormal one it is usually distinctly receding. When freshly dug, the Pearl has a distinct pinkish or light-purple tinge around the eyes, particularly at the seed end; exposure to the light or prolonged storage seems to reduce the color to such an extent that it is scarcely, if at all, visible. Skin varying from a dull white or a dull russet or brownish white, in the case of the Pearl and People's, to a deep violet-blue, with few, many, or no creamy-white splashes, particularly around the eyes (as in Blue Victor). Sprouts have base, leaf scales, and tips slightly or distinctly suffused with light lilac in the Pearl and People's, while those of the Blue Victor are a vinous mauve. A comparison of Plate XVII and of figures 1 and 2 of Plate XVIII discloses the remarkable similarity in shape of the Pearl and Blue Victor tubers.

As previously stated, the varieties belonging to this group are classified as follows: Section 1.—Pearl and People's. Section 2.—Blue Victor.

11.—PEACHBLOW GROUP.

The potatoes of the Peachblow group have in the past occupied a very prominent place among the cultivated varieties, but at the present time they are little grown commercially outside of a rather restricted area in Colorado and in a limited way as a late crop in Maryland and Virginia. Most of the older people of the present generation can remember when the Old Jersey Peachblow was a popular home and commercial variety, but, like most other widely grown varieties of its time, it seems to have had its day and is now rarely found, except in the collections of the older amateur potato enthusiasts. This group is characterized by the extreme health and vigor of its vines. It includes some early varieties, but they are mostly late

¹ Fitch, C. L. Productiveness and degeneracy of the Irish potato. Colo. Agr. Exp. Sta. Bul. 176, 16 p., illus., 1910.



TWO POTATOES BELONGING TO GROUP 8, SECTION 1.

Tuber 288 is Gold Coin; tuber 413, Gurney's White Harvest.

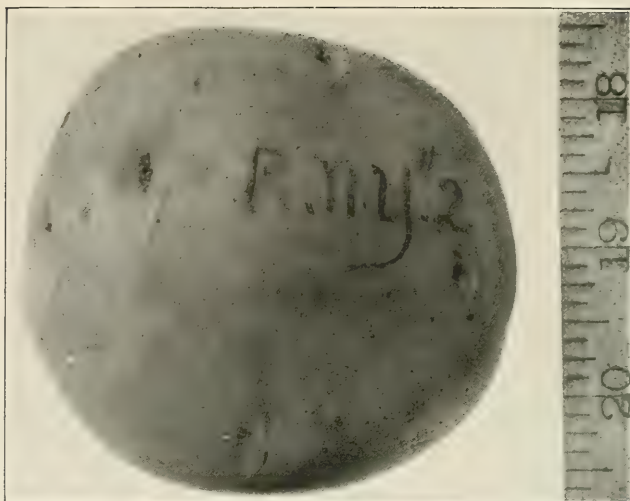


FIG. 1.—A GOOD SPECIMEN OF THE RURAL NEW YORKER No. 2.



FIG. 2.—FOUR VIEWS OF THE CARMAN No. 3.
POTATOES BELONGING TO GROUP 9.



A GOOD SPECIMEN OF THE PEARL POTATO (GROUP 10, SECTION 1).

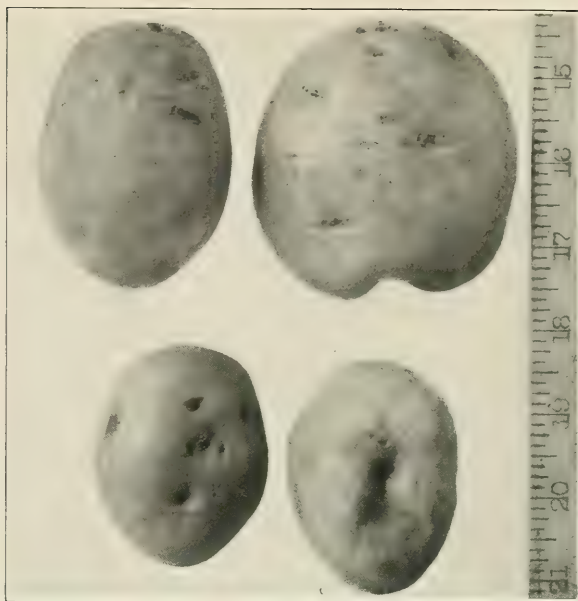


FIG. 1.—FOUR VIEWS OF THE PEARL (SECTION 1).

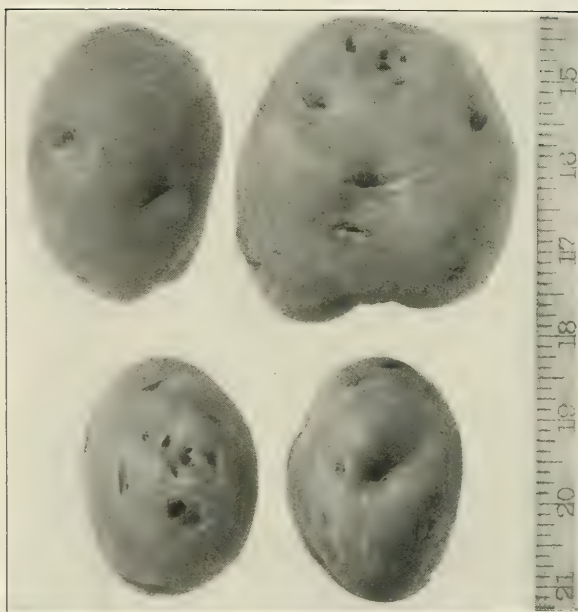


FIG. 2.—FOUR VIEWS OF THE BLUE VICTOR (SECTION 2).

POTATOES BELONGING TO GROUP 10.



TYPICAL TUBERS OF THE IMPROVED PEACHBLOW POTATO (GROUP 11), AS GROWN AT CARBONDALE, COLO.

maturing. Plate XIX illustrates two typical tubers of the Improved Peachblow.

Description.—Vines strong, erect, healthy, vigorous, and deep rooted. Stems large, strong, woody, and medium green in color. Leaves medium in abundance, rather thick, rugose or crumpled, medium to large in size and rather dark green. Flowers usually abundant, purple, and inclined to set fruit rather freely when conditions are favorable. Tubers round to round-flattened or round-oblong. Eyes medium to numerous and shallow to deep, depending upon the variety, invariably suffused with carmine or crimson, the intensity of which is more or less variable. Skin creamy white to white splashed with crimson or magenta, or flesh colored or light to dark pink, in the case of the McCormick and the Perfect Peachblow. Sprouts have base, leaf scales, and tips of reddish violet.

The varieties belonging to this group are as follows:

Dykeman.	New Improved Peachblow (Nichol's).
Early Peachblow (Hall's).	New White Peachblow (Thorburn's).
Extra-Early Peachblow.	Nott's Peachblow.
Improved Peachblow (Rand's, Pl. XIX).	Perfect Peachblow (Rand's).
Jersey Peachblow.	White Peachblow.
McCormick.	

VARIETAL DESCRIPTIONS.

The accompanying varietal descriptions, except where otherwise indicated, have all been obtained from the sources of information mentioned in the references. This information is not always stated in exactly the same order in which it occurs in the book, magazine, or seed catalogue from which it is taken, changes being necessary in order to follow a logical sequence in the presentation of available facts. The list here presented includes only about one-fifth of the varieties upon which data have been collated. In determining which varieties should be included in this list, the writer has tried to keep in mind the present or the past commercial importance of the variety, its value from the standpoint of the plant breeder, and its general interest to the older potato enthusiasts. Doubtless in the process of selection some varieties have been included which could have been dispensed with, while others have been left out which should have been included. Where comments have been made by the writer, and particularly where there has been a suggestion of criticism as to the renaming of an old variety or its resemblance to an existing one, it has been done with the intention of directing the reader's attention to these points. The main object in publishing these data is to make available such information as it has been possible to collect during the past ten years. It is important that the plant breeder should know the parentage of the varieties with which he is working, in order that he may have some idea as to what can be expected from the union of any given parents. It is equally desirable that the potato specialist and the up-to-date grower should have at hand the original published

description, incomplete though it may be, of the variety or varieties with which they are dealing.

Acme. Synonym of *ACME, EARLY*.

Acme, Early. Synonym, *Acme.* (Group 5.) Claimed by Vaughan to be a seedling of a Snowflake vine which grew between Early Rose and Early Ohio. Darling & Beahan say it is a seedling of Early Ohio.

Description.—Ripens in advance of Early Ohio. Vines upright, strong. Tubers oblong; eyes yellow; skin flesh color; flesh white. References: Vaughan's seed catalogue, 1894, p. 23; 1895, p. 23. Darling & Beahan say, "Earlier than Early Ohio and much stronger and ranker in growth. Vines tall and strong. Tubers exact counterpart in shape, color, and markings of Early Ohio and Early Six Weeks." Reference: Darling & Beahan's catalogue, 1908, p. 8.

Note.—The variety which has been grown in the Department of Agriculture collection as *Acme* or *Early Acme* is in every respect similar to *Early Ohio*. In all probability it is simply a selected strain of *Early Ohio* or a seedling, as claimed by Darling & Beahan.

Albino, Early. See *EARLY ALBINO*.

Albino, Early White. See *EARLY WHITE ALBINO*.

Alexander's New Extra-Early Beauty. See *BEAUTY, ALEXANDER'S NEW EXTRA-EARLY*.

Alexander's Reliance. See *RELIANCE, ALEXANDER'S*.

Alpha. Originated by C. G. Pringle, Charlotte, Vt., in 1870. Claimed to be a seedling of *Early Rose* crossed with *Sebec*. Introduced by B. K. Bliss & Sons in 1876.

Description.—Season early. Stalks short and close jointed, seldom exceeding a foot in height; leaves broad, light green, and shining above. Tubers medium size, oblong, somewhat flattened; eyes but slightly depressed; skin clear white with slight tinge of red about the eyes; flesh white. References: B. K. Bliss & Sons' circular of potato premiums, 1876; B. K. Bliss & Sons' potato catalogue, 1877, p. 10.

American Giant. Originated in western New York. Parentage not given

Description.—Two weeks later than *Early Rose*. Vines vigorous and healthy. Tubers unusually large, very long, compact in hill; eyes many. Reference: B. K. Bliss & Sons' potato catalogue, 1881, p. 11. Olds says, "In season, color, and shape it is much the same as *Empire State*. Tubers, however, are thicker, longer, and fewer in a hill." Reference: L. L. Olds's seed-potato catalogue, 1891, p. 12.

Note.—The *American Giant* produces large, rough, coarse-fleshed, and low-quality tubers. It is very generally used in the preparation of potato chips, for which it seems to be admirably adapted.

American Wonder. Originated by L. Wall; seedling of *Wall's Orange*. Introduced by James Vick in 1892.

Description.—Vines strong and branching, somewhat resembling those of the *Peachblow*; foliage rich, dark green, offset by a mass of beautiful white bloom. Tubers large, uniform in size, elongated, slightly compressed; eyes few and nearly flush with the surface; skin white. Approaches very close to a blight and rot proof potato. References: Vick's Floral Guide, 1892, pp. iii and 64; 1893, p. 28.

Note.—There is a red-skinned variety of the same name, which is sometimes confused with the true *American Wonder*.

Arcadia. (Group 9, section 1.) Origin not known.

Description.—Medium-late potato of most desirable form and appearance. Tubers oval, somewhat flattened, pure white; eyes few and shallow. Reference: Farmer Seed Co.'s catalogue, 1899, p. 33.

Aroostook Beauty. Originated in Aroostook County, Me.: seedling of Early Rose. Introduced about 1893.

Description.—Hardier and more prolific than Early Rose. Reference: Rural New Yorker, vol. 52, 1893, p. 266. Ross Brothers say, "Plants do not blossom. Tubers large, very smooth, about the shape of Carman No. 1; skin rose colored." Reference: Ross Bros.' catalogue, 1902, p. 19.

Note.—This variety is one of numerous Rose seedlings of no particular value.

Aroostook Wonder. Originated in Caribou, Me. Introduced by the G. W. P. Jerrard Co. in 1908.

Description.—Season medium. Vines strong and sturdy; foliage luxuriant and deep green. Tubers round, smooth; eyes small and shallow; skin creamy white; flesh white and fine grained. References: G. W. P. Jerrard Co.'s catalogue, 1906, p. 1; 1911, p. 1.

Note.—The illustration shows the tubers to be elongated, cylindrical, and flattish.

Badger State. Originated by F. R. Huebner, Manitowoc, Wis., in 1885; claimed to be a seedling of Burbank crossed with Wall's Orange. Introduced in 1889.

Description.—Vines very strong. Tubers large, oblong; skin white. A good shipper. Reference: Vaughan's seed catalogue, 1891, p. 26. Frank Ford & Sons say, "Vines strong. Tubers medium, long, somewhat pointed, oval, large to very large; eyes numerous, generally prominent; skin white, sometimes netted." Reference: Frank Ford & Son's seed catalogue, 1890, p. 23.

Banner, Livingston's. Originated in central Ohio, in 1889 by M. M. Miesse; claimed to be a seedling from a package of extra-hybridized potato seed. Introduced by A. W. Livingston & Sons in 1894.

Description.—Main-crop variety. Tubers a little oblong, slightly flattened on the sides, smooth, regular; eyes few, shallow; skin light cream and very slightly russety in texture. Reference: A. W. Livingston & Sons' seed catalogue, 1894, pp. 88-89.

Beauty. Season early.

Note.—This variety is Noroton Beauty or Quick Lunch, renamed and introduced to the trade by a leading southern firm under the name of Beauty. Reference: Tait & Sons' catalogue, 1911.

Beauty, Alexander's New Extra-Early. Origin not known.

Description.—Extra early and extra prolific; earlier than Triumph and Rose, and producing twice as many select and marketable potatoes. Tubers are like Triumph in shape; skin creamy white, slightly netted with lighter color; flesh pure white. Reference: O. H. Alexander's catalogue, 1912, p. 45.

Note.—In all probability Noroton Beauty or White Triumph.

Beauty, Aroostook. See AROOSTOOK BEAUTY.

Beauty, Brownell's. Originated by E. S. Brownell, Essex Junction, Vt., in 1870; claimed to be a seedling of Early Rose crossed with White Peachblow. Introduced by B. K. Bliss & Sons in 1873.

Description.—Season medium. Vines of medium growth; foliage deep green and very healthy. Tubers medium to large, oval, somewhat flattened, very fair and smooth, growing compactly in hill and easily dug; eyes few, small, nearly even with the surface; skin reddish or a deep flesh color; flesh white. Reference: B. K. Bliss & Sons' potato catalogue, 1873, p. 4; 1874, p. 4.

Beauty, Hampden. See HAMPDEN BEAUTY.

Beauty of Hebron, Early. (Group 6.) Originated by E. L. Coy, Hebron, N. Y.; claimed to be a seedling of Garnet Chili. Introduced in 1878 by J. M. Thorburn & Co. Reference: Cultivator and Country Gentleman, vol. 45, 1880, p. 468.

Description.—About as early as Early Rose and a much better cropper. Strongly resembles Early Rose in shape and color. Reference: J. J. H. Gregory's seed

catalogue, 1879, p. 55. Ford describes it as follows: "Very early, earlier than Early Rose. Tubers oblong-oval, uniform in size; eyes few and smooth; skin light pink, nearly white; excellent quality." Reference: Frank Ford's seed catalogue, 1881, p. 13.

Note.—A leading commercial variety 30 years ago, but little grown at the present time.

Beauty of Hebron, Improved. (Group 6.) Claimed to be a seedling of Peerless crossed with Beauty of Hebron.

Description.—Earlier than the old Beauty of Hebron and of superior quality, but similar in shape and color. So similar to Vaughan's Early Northern as to be indistinguishable from it. Reference: C. W. Eichling's seed and floral catalogue, 1900, p. 27.

Beauty of Hebron, Late. Synonym, *White Elephant*. (Group 6.) Originated in Hebron, N. Y.; claimed to be a sport of the Early Beauty of Hebron.

Description.—Bliss says, "Tubers oblong and of extra size; skin white; flesh white." Reference: B. K. Bliss & Sons' potato catalogue, 1883, p. 20. Gregory says, "This is a new seedling from New York State which closely resembles the early variety of the same name." Reference: J. J. H. Gregory's seed catalogue, 1882, p. 54.

Note.—In the opinion of the writer, Bliss's description of the color of the skin is misleading, as in all probability there was a light-pink tinge.

Beauty of Vermont. Originated by E. S. Brownell, Essex Junction, Vt., in 1870; claimed to be a seedling of Early Rose.

Description.—Season medium; ripens about a week later than Early Rose. Vines healthy, strong. Tubers medium to large, oval-flattened and roundish, varying somewhat like those of the Early Rose, smooth and fair; eyes few and small; skin very much like that of its parent; flesh light straw color. Reference: *The Horticulturist*, vol. 28, 1873, p. 73.

Best, Brownell's. Originated by E. S. Brownell, Essex Junction, Vt., in 1875; claimed to be a seedling of Excelsior. Introduced by B. K. Bliss & Sons in 1882.

Description.—Season medium. Tubers grow compactly in hill; oblong and somewhat flattened in shape; eyes few and entirely smooth; skin white, shading to russet; flesh white and fine grained. References: B. K. Bliss & Sons' seed catalogue, 1882, p. 93; B. K. Bliss & Sons' potato catalogue, 1882, p. 6; 1883, p. 7; *Pharo's Chart*, 1888.

Bethel Beauty. (Group 8, section 1.) Originated by Eli A. Lewis, Bethel, Vt., about 1901 to 1903; claimed to have been found among a lot of tomato seedlings. Introduced by Fred F. Hackett, Bethel, Vt.; probably because of this fact the credit of having originated the variety has been erroneously assigned to him. References: *New England Homestead*, April 22, 1911, p. 610; March 25, 1911, p. 477.

Description.—Season late. Vines strong growing; foliage abundant; stems erect in early part of season, after which they gradually assume a more or less decumbent position. Tubers large, long, more or less flattened, sometimes slightly constricted, numerous and somewhat spreading in hill; eyes numerous, slightly depressed; skin glistening white. A new variety worthy of further trial.

Big Cropper, Knowles's. Synonym of KNOWLES.

Big Crop Potato, Knowles's. Synonym of KNOWLES.

Bill Nye. Claimed to be a seedling of Beauty of Hebron crossed with Belle. Introduced in 1891.

Description.—Main-crop variety. Tubers kidney shaped; eyes unusually shallow for a late potato; skin white, smooth. Reference: A. W. Livingston's seed

catalogue, 1891, p. 11. The Rural New Yorker says, "As early as the Early Rose. Tubers rather long, oblong, flattened; eyes few, not prominent; skin buff; flesh nearly white." Reference: Rural New Yorker, vol. 50, 1891, p. 143.

Note.—These two descriptions seem to vary with respect to season of maturity, but it is doubtful whether they are distinct varieties. This variety seems to have been offered in 1891 by at least three seed firms, viz, Peter Henderson, A. W. Livingston, and Phillips & Sons.

Bird, Early. See EARLY BIRD.

Black Chenango. See CHENANGO, BLACK.

Black Mercer. Synonym of CHENANGO, BLACK.

Blightless, Late. See LATE BLIGHTLESS.

Blightless Wonder, Smith's. (Group 8, section 1.) Origin not known.

Description.—Season late. Vines very large and strong, dark green. Tubers long, smooth, somewhat larger in the middle; skin straw color. Reference: Smith Bros. Seed Co.'s catalogue, 1911, p. 10.

Bliss's Triumph. Synonym of TRIUMPH.

Bliss, White. Synonym of WHITE TRIUMPH.

Blue Noses. Synonym of MERCER.

Blue Victor. (Group 10, section 2.) Origin not given.

Description.—Season late. Tubers resemble those of the Pearl in shape, being short, broad, and heavily shouldered; skin dark blue; flesh white and fine grained. References: Rural New Yorker, vol. 44, 1885, p. 10; Harnden Seed Co.'s catalogue, 1899, p. 54.

Note.—Vines of medium size and vigor, with rather upright habit of growth; stems slightly to considerably streaked with purple; otherwise very similar to those of the Pearl. Tubers similar in shape to those of the Pearl, but the skin is of a deep violet-blue color, sparsely or more or less freely splashed with creamy yellow, particularly around the eyes. Sprouts rather deeply suffused with vinous mauve.

Blush, New. Synonym of RURAL BLUSH.

Blush, Rural. See RURAL BLUSH.

Bonanza. Origin not known. Date of introduction uncertain. Frank Ford & Son mention it in their 1885 catalogue, p. 14, but they do not claim to have introduced it. The Iowa Seed Co., in its 1895 catalogue, p. 42, claim to have introduced it in 1887. From this evidence it would appear that there are either two distinct varieties or else that the claim made by the Iowa Seed Co. is not valid. In like manner E. S. Cannan, Martin Bovee, and Thomas Craine are mentioned as the originators.

Description.—A new variety of fine appearance, productive, and of good quality. Tubers oval or oblong, more or less flattened, medium to large; eyes numerous, some prominent in clusters, others depressed, especially at the seed end; skin light red, slightly netted. Reference: Frank Ford & Son's seed catalogue, 1885, p. 14. The Iowa Seed Co. says, "This magnificent variety which we introduced in 1887 is a medium-late potato. Tubers large, oblong, somewhat flattened; skin smooth; flesh firm, white." Reference: Iowa Seed Co.'s catalogue, 1895, p. 42.

Note.—Further mention of this variety by Cole would seem to indicate that it is identical with the one described by Frank Ford & Son. Reference: Cole's Garden Annual, 1905, p. 56.

Boston Market. Synonym of EARLY SEBEC.

Bovee. Synonym, *Early Bovee*. (Group 6.) Originated as a seedling by Martin Bovee, of Northville, Mich.

Description.—Season early; claimed by Bovee to be 13 days earlier than Early Ohio. As perfect in shape as the well-advertised Freeman and less variable. Reference: Rural New Yorker, vol. 53, 1894, p. 490. Maule says, "Season early to extra early. Originated by Martin Bovee, of Michigan. Tubers long, oval; skin pink or flesh color, well netted." Reference: W. H. Maule's seed catalogue, 1900, p. 60.

Note.—Bovee's claim regarding earliness is not substantiated.

Breakfast, Early. See EARLY BREAKFAST.

Breck's Chance. See CHANCE, BRECK'S.

Bresee's No. 2. Synonym of PROLIFIC, BRESEE'S.

Bresee's No. 4. Synonym of KING OF THE EARLIES.

Bresee's No. 6. Synonym of PEERLESS.

Bresee's Prolific. See PROLIFIC, BRESEE'S.

Brownell's Beauty. See BEAUTY, BROWNELL'S.

Brownell's Best. See BEST, BROWNELL'S.

Brownell's Eureka. See EUREKA, BROWNELL'S.

Brownell's Superior. See SUPERIOR, BROWNELL'S.

Brownell's Winner. See WINNER, BROWNELL'S.

Bruce's White Beauty. Synonym of WHITE BEAUTY.

Burbank. Synonym of BURBANK'S SEEDLING.

Burbank, Russet. See RUSSET BURBANK.

Burbank's Seedling. Synonym, *Burbank*. (Group 7, section 1.) Originated by Luther Burbank in 1873; claimed to be a seedling of Early Rose. Introduced by J. J. H. Gregory in 1876.

Description.—Season medium late. Gregory says, "I send out this season for the first time the new potato Burbank's Seedling. This, like the Early Ohio, is a seedling of Early Rose, but is of Massachusetts origin. Ranks between the very early and the very late varieties. Has but few eyes, which are sunk but little below the surface; unlike its parent it is white skinned. In quality it is firm, fine grained, of excellent flavor either boiled or baked, dry, and floury." Reference: J. J. H. Gregory's seed catalogue, 1876, p. 51. Frank Ford says, "Late, immensely productive. Tubers large, long, round; eyes full; skin nearly smooth, white; quality among the best. A good sort for market." Reference: Frank Ford's seed catalogue, 1881, p. 13.

Note.—It is well known that Burbank's Seedling possesses a relatively large number of eyes.

Burpee's Extra Early. See EXTRA EARLY, BURPEE'S.

Burpee's Superior. See SUPERIOR, BURPEE'S.

California Russet. (Group 7, section 2.) Origin not known.

Description.—Season late; a new variety of great merit. Tubers medium size, long, oval; eyes perfectly level with surface of tuber and devoid of knobby protuberances; skin a beautiful russet; unexcelled in quality. Reference: Dakota Improved Seed Co.'s catalogue, 1908, p. 16.

Note.—Very similar to Cambridge Russet, possibly identical.

Cambridge Russet. (Group 7, section 2.) Origin not known.

Description.—Season late; very productive. Vines vigorous, dark green, and have proved absolutely blight and drought proof. Tubers round to oblong; eyes shallow; skin russet brown, covered with a fine vein work. Reference: Ross

Bros.' catalogue, 1899, p. 10. The H. N. Hammond Seed Co. lists the variety as California Russet or Cambridge Russet, evidently regarding them as identical. Reference: H. N. Hammond Seed Co.'s catalogue, 1901, p. 16.

Note.—Similar to California Russet, if not identical with it.

Campbell's Late Rose. See LATE ROSE, CAMPBELL'S.

Carman. Originated by O. H. Alexander, of Charlotte, Vt., in 1884; claimed to be a seedling of Early Vermont crossed with Beauty of Hebron.

Description.—Season late. Tubers oblong, flattened, shapely and smooth; eyes few; skin flesh colored; flesh white. Reference: Rural New Yorker, vol. 45, 1886, p. 33.

Carman No. 1. Synonym, *Rural New Yorker No. 1.* (Group 8, section 1.) Originated by E. S. Carman in 1889; claimed to be a seedling of seedlings raised through several generations. Introduced by J. M. Thorburn & Co. in 1894.

Description.—Season medium. Resembles Rural New Yorker No. 2 in shape and also in having very few and shallow eyes; flesh white. Quality perfect. Reference: J. M. Thorburn & Co.'s seed catalogue, 1894, p. 9. Gregory says, "Intermediate between early and late. Vines remarkably stout and stocky," etc. Reference: J. J. H. Gregory's seed catalogue, 1895, p. 4.

Note.—In describing the Rural New Yorker No. 1 and announcing that single, small tubers will be sent to each subscriber next fall, the following reference is given with respect to change of name: "It will be introduced as Carman No. 1, that name having been selected by those who control the stock. We would prefer to have it called the Rural New Yorker No. 1, but that name is, commercially speaking, open to several valid objections." Reference: Rural New Yorker, vol. 51, 1892, p. 875.

Carman No. 3. (Group 9, section 1.) Originated by E. S. Carman in 1888; claimed to be a seedling of a seedling. Introduced in 1895 by J. M. Thorburn & Co., who say of it: "The Carman No. 3, which we now offer for the first time is, like the Carman No. 1, a seedling from seedlings raised through several generations by the experienced originator whose name they bear."

Description.—Season late. Resembles the Carman No. 1 except that tubers are a little more elongated. They grow compactly in the hill and the plants resist drought well. Vines strong and vigorous; foliage heavy and dark green; tubers large; eyes very shallow and but few in number; skin and flesh of extreme whiteness. Reference: J. M. Thorburn & Co.'s seed catalogue, 1895, p. 10.

Carter. Originated from seed by John Carter, of Savoy, Berkshire Co, Mass., about 1835.

Description.—A medium-sized, roundish-flattened potato, once esteemed the finest of all varieties, but at present nearly or quite superseded by the Jackson White, of which it is supposed to be the parent; eyes rather numerous and deeply sunk; skin white; flesh very white. References: Field and Garden Vegetables, vol. 1, 1863, p. 59; Country Gentleman, vol. 12, 1858, p. 349; vol. 26, 1865, p. 15.

Centennial. Originated by E. S. Brownell, Essex Junction, Vt., in 1874; claimed to be a seedling of Brownell's Beauty crossed with White Peachblow. Introduced by B. K. Bliss & Sons in 1877.

Description.—A second early or medium. Vines upright, stout, vigorous, and of medium height; foliage dark green and very healthy. Tubers compactly clustered about the base of the stalks, nearly round, somewhat flattened, very symmetrical; eyes few and quite small, slightly depressed near the seed end; stem set in a shallow, round basin; skin deep red, smooth, and uniform in coloring; flesh white. References: B. K. Bliss & Sons' potato catalogue, 1877, p. 7; 1878, p. 16; Cultivator and Country Gentleman, vol. 41, 1876, p. 809; Peter Henderson & Co.'s seed catalogue, 1877, p. 67.

Champion. Synonym, *Vermont Champion*. Originated by A. Rand, Charlotte, Vt., in 1877; claimed to be a seedling of Compton's Surprise crossed with White Peachblow. Introduced by B. K. Bliss & Sons in 1882.

Description.—Vines strong and upright, bearing seed balls freely. Tubers large, roundish oval; skin silvery white; flesh white. References: B. K. Bliss & Sons' seed catalogue, 1882, p. 93; B. K. Bliss & Sons' potato catalogue, 1882, p. 7; 1883, p. 8.

Chance, Breck's. Originated in Connecticut in 1888; claimed to be a sport from Pearl of Savoy. Introduced by Joseph Breck & Sons in 1895.

Description.—Matures as early as Pearl of Savoy, Houlton Rose, etc., and is far superior to them in quality. Vines of robust growth. Tubers roundish oval; skin rough; flesh white. Reference: Joseph Breck & Sons' seed catalogue, 1895, p. 19.

Charles Downing. (Group 8, section 2.) Originated by O. H. Alexander, Charlotte, Vt.; parentage not known. Introduced by Frank Ford & Sons in 1887.

Description.—Very early and productive, the very best of the Snowflake family. Vines very strong. Tubers oblong, oval, very smooth, medium size; eyes few; skin white, netted. Reference: Frank Ford & Sons' seed catalogue, 1887, p. 16. Tillinghast says, "Strong, nearly erect, growth 22 inches; foliage green. Tubers scattered in hill, smooth, and of medium size, bright color." Reference: I. F. Tillinghast's catalogue, 1887, p. 12.

Note.—Apparently jointly introduced by Frank Ford & Sons and I. F. Tillinghast in 1887.

Chenango. Synonym of **MERCER**.

Chenango, Black. Synonym, *Black Mercer*. Origin not known.

Description.—Season late; yields well. Color of outside nearly black, of inside purple. Reference: Magazine of Horticulture, vol. 23, 1857, p. 60. In Field and Garden Vegetables the following description is found: "Synonym, *Black Mercer*. Plant vigorous and generally of healthy habit. Tubers nearly of form of Lady's Finger, but larger; skin very deep purple or nearly black; flesh purple in its crude state and when cooked. Quality good." Reference: Field and Garden Vegetables, vol. 1, 1863, p. 58.

Chenango, White. Synonym, *Mercer*. Origin not known. There is a strong likelihood that this variety is identical with the White Mercer. An old and favorite sort with many, especially for early planting. Has rotted badly for several years past. References: Magazine of Horticulture, vol. 23, 1857, p. 59; C. E. Hovey & Co.'s catalogue, 1857, p. 14. The Country Gentleman says, "The Chenango and Mercer we believe are identical." Reference: Country Gentleman, vol. 13, 1859, p. 138.

Chicago Market. Originated by D. S. Heffron, Utica, N. Y., in 1875; claimed to be a seedling of Early Goodrich crossed with Early Rose. Introduced by James Vick in 1879.

Description.—Season early; ten days earlier than the Rose and more productive. Vines short and stout; leaves above medium, deep green. Tubers forming in clusters, shape oval to cylindrical, not flattened; eyes shallow and few in number; skin russety, lighter in color than that of the Rose; flesh white. Reference: Vick's Floral Guide, 1880, p. 86.

Note.—The variety now offered by some seedsmen under the name of Chicago Market is very similar to the Early Ohio.

Clark's No. 1. (Group 4, section 1.) Originated by William Clark, of New Hampshire, in 1876; claimed to be a seedling. Introduced by J. J. H. Gregory and by the United States Government in 1877-8.

Description.—Season early; earlier than Early Rose and yields a quarter to a third larger crop. Closely resembles Early Rose in appearance. References:

J. J. H. Gregory's seed catalogue, 1880, p. 53; B. K. Bliss & Sons' potato catalogue, 1881, p. 15.

Note.—In all probability a seedling of Early Rose.

Clark's Pride. See PRIDE, CLARK'S.

Climax. Originated by D. S. Heffron in 1864; claimed to be a seedling of Early Goodrich.

Description.—Earlier than Early Goodrich; a few days later than Early Rose. Vines stout, erect; leaves large. Tubers about medium size; cylindrical, swelled out at center, eyes shallow, but strongly defined; skin considerably netted or russet, tough, white; flesh entirely white, solid, never hollow. Reference: Curtis and Cobb's Floral and Kitchen Garden Directory, p. 144.

Clyde. (Group 8, section 1.) Originated by W. E. Johnson, Richmond, Me., in 1902; claimed to be a seedling of Norcross crossed with Green Mountain. Introduced by the Johnson Seed Potato Co. in 1906.

Description.—Vines upright, heavy, dark green, with profuse bloom. Tubers oval, somewhat flattened; skin white. Resembles Green Mountain in every way. Reference: Chas. F. Saul's seed catalogue, 1908, p. 42.

Columbus. (Group 6.) Originated in New Hampshire; parentage not given. Introduced by Frank Ford & Sons in 1893.

Description.—A second early. Tubers long, oval, somewhat pointed at stem end, cross section roundish oval; eyes abundant, compound, with a distinct brow, some prominent, others depressed; skin light flesh color, splashed and streaked with bright pink, considerably russeted. Reference: Frank Ford & Sons' seed catalogue, 1893, p. 36.

Commercial. Claimed to be a seedling of Wilson Rose. Introduced by W. H. Maule in 1899.

Description.—Season late; a quick-maturing, main-crop variety. Tubers oblong, rather broad and thick, somewhat resembling those of Carman No. 3 in shape; eyes shallow; skin is that peculiar russet which characterizes all the best potatoes, and in addition the pink or rosy hue of its great ancestor is clearly visible. Reference: W. H. Maule's seed catalogue, 1899, pp. 8-9.

Compton's Surprise. Originated by D. A. Compton in 1870; claimed to be a seedling of Prince Albert crossed with Long Pinkeye. Introduced by B. K. Bliss & Sons in 1873.

Description.—Season late; somewhat stoloniferous; claimed that yields of 826 bushels per acre have been obtained. Tubers large, oval-oblong; eyes sunken, brow prominent; skin reddish purple, smooth; flesh white. Its starch content is believed to be greater than that of any variety extant. Reference: B. K. Bliss & Sons' potato catalogue, 1874, pp. 8-10.

Corliss's Matchless. See MATCHLESS, CORLISS'S.

Country Gentleman. (Group 6.) Originated by the G. W. P. Jerrard Co., Caribou, Me.; parentage not given. Introduced by the originators in 1896.

Description.—Season medium late, about half way between New Queen and White Elephant. Tubers closely resemble those of the New Queen and Beauty of Hebron save that the color is more marked than in either of these varieties; eyes very shallow, numerous sprouts to the eyes; the blush and white markings cover the skin in a peculiar mottled manner. Reference: G. W. P. Jerrard Co.'s catalogue, 1896, p. 2. Vines of medium vigor and spreading habit; flowers white. Tubers long, cylindrical; eyes medium; skin light buff; flesh white. Reference: Rural New Yorker, vol. 56, 1897, p. 7. Oblong in shape, with strong eyes, a fine blush and white, mottled skin. Reference: Angell Seed Co.'s manual, 1899, p. 27.

Craine's June Eating. See JUNE EATING, CRAINE'S.

Craine's Keeper. See KEEPER, CRAINE'S.

Crine's Lightning. See LIGHTNING, CRINE'S.

Crown Jewel. (Group 6.) Claimed to be a seedling of Early Ohio.

Description.—Season very early, a week earlier than Early Ohio, and more productive. Vines vigorous. Tubers oblong, round, or oval; eyes numerous, shallow; skin pure white, finely netted. Reference: Frank Ford & Sons' catalogue, 1889, p. 24. The Rural New Yorker quotes Johnson & Stokes as follows: "Tubers variable in shape, oftenest as shown in our illustration [elongated, obovate, flattened]; eyes medium as to number and prominence; skin whitish." Reference: Rural New Yorker, vol. 47, 1888, p. 161 (fig. 58).

Dakota Red. Originated by O. H. Alexander, Charlotte, Vt., from Pringle's hybridized seed. Introduced in 1883 by Hiram Sibley & Co.

Description.—Season late. Vines stocky, stand drought well. Tubers large, handsome, long, round; eyes irregular; skin firm, reddish flesh color; flesh white. Reference: Hiram Sibley & Co.'s seed catalogue, 1883, p. 123. W. W. Rawson says, "Medium late; vines erect and stocky. Tubers large, oblong and slightly wedge shaped; skin smooth, firm (on some soils russety); flesh white." Reference: W. W. Rawson's catalogue, 1885, p. 19.

Dakota Seedling. Originated by John Moore, of Dakota; parentage not given. Introduced by J. A. Everitt, Indianapolis, Ind.

Description.—Tubers large, ovoid in form; eyes shallow; skin smooth, very attractive in appearance. Reference: Cultivator and Country Gentleman, vol. 53, 1888, p. 390. Delano Bros. say, "Tubers oblong; eyes few and raised; skin pink and very smooth; flesh white. Unsurpassed as a keeper." Reference: Delano Bros.' catalogue, 1890, p. 13.

Daughter of Early Rose. (Group 4.) Origin unknown, except as suggested by its name. Introduced by the Salzer Seed Co. in 1901.

Description.—Resembles the Early Rose in shape, but better in quality and more productive. Reference: Salzer Seed Co.'s catalogue, 1901, p. 106.

Dearborn. Originated on the Vaughan farm, Henderson, Mich.; parentage not given, other than that it is a seedling. Introduced by Vaughan in 1912.

Description.—Season medium early, maturing a little later than Irish Cobbler. Strong, thrifty growth, upright habit; leaves large, dark green. Tubers nearly round, sometimes slightly flattened; skin densely netted; flesh white. Reference: Vaughan's seed catalogue, 1912, p. 7.

Delaware. (Group 8, section 1.) Originated by A. Rand, of Shelburne, Vt.; claimed to be a seedling of Early Rose crossed with Excelsior. Introduced by J. J. H. Gregory in 1888.

Description.—Season medium early. Tubers large; skin and flesh white. Reference: J. J. H. Gregory's seed catalogue, 1888, p. 4. The Rural New Yorker says, "It seems to be an intermediate or late intermediate. General shape is variable, though often rather long and round, occasionally a little flattened; eyes medium as to number and somewhat deep." Reference: Rural New Yorker, vol. 46, 1887, p. 735.

Dibble's Russet. See RUSSET, DIBBLE'S.

Dixie, Early. See EARLY DIXIE.

Dreer's Early Standard. See EARLY STANDARD, DREER'S.

Dreer's Standard. See STANDARD, DREER'S.

Durham, Early. See EARLY DURHAM.

Dykeman. Synonyms, *Early Pinkeye*, *Round Pinkeye*. (Group 11.) Listed by Pharo as a seedling of promiscuous hybridized seed.

Description.—Season early. Plant of medium strength and vigor, rarely producing seed or blossoms. Tubers large, roundish, often oblong; eyes moderately sunken and rather numerous; skin white, clouded with purple at the stem end and about the eyes; flesh white or yellowish white. Reference: Field and Garden Vegetables, vol. 1, 1863, p. 61.

Early Acme. See ACME, EARLY.

Early Albino. (See also EARLY WHITE ALBINO.) (Group 3.) Originated by L. H. Read, Cabot, Vt.; claimed to be a new seedling from a cross between Early Ohio and Snowflake. Introduced in 1887. References: Angell & Co.'s seed catalogue, 1895, p. 27; E. W. Burbank Seed Co.'s catalogue, 1895, p. 16.

Description.—Season early; as early as Hebron. Tubers long, round, slightly flattened; eyes medium; skin buff white. Reference: Rural New Yorker, vol. 46, 1887, p. 243. Frank Ford & Sons describe it as follows: "Very early; vines medium height and stocky. Tubers oblong, oval; eyes few with a slight pink tint; skin creamy white, thickly netted." Reference: Frank Ford & Sons' seed catalogue, 1888, p. 22.

Note.—The latter description is more accurate than the former, particularly with respect to the pink tint around the eyes.

Early Beauty of Hebron. See BEAUTY OF HEBRON, EARLY.

Early Bird. Origin not given.

Description.—Vines very strong, healthy, very hardy, free from blight, inclined to be decumbent; foliage rather light colored. Tubers rather long and blunt at the ends, with nearly round cross section, regular in shape and free from knobs and prongs; skin creamy white; flesh pure pearly white. Reference: Darling & Beahan's seed catalogue, 1909, p. 52.

Note.—The tubers secured by the Department of Agriculture from Darling & Beahan as Early Bird do not answer to the above description with respect to the color of skin, as the stem end is more or less suffused with pink.

Early Bovee. Synonym of BOVEE.

Early Breakfast. Claimed to be a new seedling.

Description.—Similar to Early Michigan in time of ripening, shape, and color. Vines stronger and not so subject to blight. Tubers inclined to grow larger and have a more russet skin. Reference: Darling & Beahan's seed catalogue, 1908, p. 6.

Early Dixie. (Group 1.) Origin not given.

Description.—Ripens early. Vines moderately vigorous. Tubers round; eyes few, somewhat indented; skin pearly white. Resembles Irish Cobbler in shape and color, but is at least 10 days or 2 weeks earlier. Reference: Wood, Stubbs & Co.'s seed catalogue, 1913, p. 34.

Note.—Practically identical with Irish Cobbler.

Early Durham. (Group 4, section 1.) Originated by C. E. Allen, Brattleboro, Vt.; claimed to be a seedling of Early Rose.

Description.—Season early; matures two weeks earlier than Early Rose and is more vigorous and prolific. Somewhat resembles Early Rose in appearance, but is so decidedly lighter colored as to be entirely distinct. References: Cultivator and Country Gentleman, vol. 44, 1879, p. 774; vol. 45, 1880, p. 23. The Rural New Yorker says, "Oblong, often rather small at both ends, as shown in fig. 158; eyes medium in number and not deep; skin light; flesh yellowish white." Reference: Rural New Yorker, vol. 45, 1886, p. 249.

Early Excelsior. Claimed to be a seedling of the Early Ohio.

Description.—Season early; 10 days to 2 weeks earlier than the Early Ohio. Vines strong, with deep-green foliage. Tubers closely resemble those of the Early Ohio in shape and color. Under favorable circumstances they are fit for use in six weeks from time of planting. Reference: Young & Halstead's catalogue, 1905, back cover page.

Early Fortune. (Group 4, section 1.) Origin not given; claimed to be a member of the Rose family. Introduced in 1893 by F. B. Mills. Reference: F. B. Mills's Garden Annual, 1895, p. 20.

Description.—Season early, somewhat earlier than Early Rose. Tubers red, with prominent red markings at each eye, as well as at seed end. Reference: G. W. P. Jerrard Co.'s catalogue, 1897, p. 6. Jerrard six years later says, "Season very early. Light amber color, red at seed end. As we know it, not strictly a Rose type. Many seedsmen are selling a Rose variety for the Early Fortune, but with us the Fortune has distinct markings peculiar to itself and can not be mistaken for any other variety if once known." Reference: G. W. P. Jerrard Co.'s catalogue, 1903, p. 9. "Resembling the New Queen in shape." Reference: R. B. Dunning & Co.'s catalogue, 1902, p. 22.

Early Goodrich. Originated by C. E. Goodrich, Utica, N. Y., in 1860; claimed to be a seedling of the Cuzco. Introduced by D. S. Heffron, Utica, N. Y., acting for the Goodrich heirs, in 1863.

Description.—Season early; as early as the well-known Early June. The Country Gentleman says: "When the Early Goodrich was only 2 years old, Mr. Goodrich made this memorandum with reference to it. 'Round to longish, sometimes with a crease at the insertion of the root; (color) white; vines and leaves much as the Copper Mine; flowers bright lilac, (produces) many balls.'" Reference: Country Gentleman, vol. 24, 1864, p. 269. The following additional description is found in the American Agriculturist: "Eyes large and full; skin white and smooth; flesh white." Reference: American Agriculturist, vol. 25, 1866, p. 56 (fig. 1).

Early Harvest. "This potato I obtained from A. F. Ellsworth, of Vermont. Mr. E. obtained it some four years ago from California." Reference: Joseph Harris's illustrated seed catalogue, 1883, pp. 65-66.

Description.—Tubers resemble those of Early Rose. Reference: Joseph Harris's illustrated seed catalogue, 1883, pp. 65-66. A more complete description is given by Frank Ford & Son: "Ripens five or six days later than Lee's Favorite. Tubers medium size, oblong, a little flattened; eyes numerous; skin light red. Fair quality." Reference: Frank Ford & Son's seed catalogue, 1884, p. 14.

Early Harvest. Originated in Kenduskeag, Penobscot Co., Me. Introduced by G. W. P. Jerrard in 1893. Reference: G. W. P. Jerrard Co.'s catalogue, 1900, p. 4.

Description.—Wonderfully early and a large yielder. Tubers average very large, oval-flattened, sometimes long-oval; eyes only slightly indented; skin nearly white, often netted. Reference: G. W. P. Jerrard Co.'s catalogue, 1894, p. 2.

Early Harvest. Originated by Clyde Somerset, a leading potato specialist of New York; claimed to have same parentage as Empire State, viz, seedling of White Elephant. First sent out for trial to a few customers under the name of No. 97.

Description.—Season medium early; handsome, highly prolific variety. Somewhat on the order of Beauty of Hebron, but the same shape as the Quick Crop. Some of the blood of the Moore & Simon's Early Snowball flows in its veins. From our personal observation we highly indorse it for light, sandy land and sandy loams along river bottoms. Reference: Moore & Simon's catalogue, 1907, p. 43.

Early Henry. Synonym of EARLY SHAW.

Early Hunt. Synonym of TRIUMPH.

Early Maine. Synonym, *Maine Rose*. (Group 4, section 1.) Originated in Maine in 1877; claimed to be a seedling of the Early Rose. Introduced by J. J. H. Gregory in 1884.

Description.—Season early. In general it closely resembles the Early Rose, but it is earlier and more productive. Reference: J. J. H. Gregory's seed catalogue, 1884, p. 3. The Rural New Yorker gives the following description: "Spreading habit of growth. Tubers oftenest cylindrical to egg shaped, as shown in our illustration; eyes not as prominent as in Early Rose; color of skin about that of the Early Rose, sometimes of a deeper pink about the eyes; flesh nearly white." Reference: Rural New Yorker, vol. 43, 1884, p. 794 (fig. 491, p. 796). Van Ornam says, "So closely resembling the Early Rose that few could tell them apart, but a better cropper and one week earlier." Reference: Van Ornam's "Potatoes for Profit," 1896, p. 75.

Early Manistee. Synonyms, *Manistee*, *Improved Manistee*. (Group 4, section 2.) Claimed to be a seedling of Early Rose. Introduced by E. F. Dibble in 1904.

Description.—Season medium early. Vines strong and vigorous. Tubers round to oblong or long, slightly flattened; eyes shallow; skin light pink or rose colored; flesh pure white. References: E. F. Dibble's farm seed catalogue, 1904; 1906, p. 6; John A. Salzer Seed Co.'s catalogue, 1908, p. 117.

Early Market. (Group 5.) Origin not given. Introduced by James Vick in 1889.

Description.—Season early. Another grand addition to the Ohio class; very productive. Tubers have the peculiar markings of the Early Ohio, but are quite distinct from that variety, being more elongated; medium to large, oval oblong; both stem and seed ends round and full; eyes flush with the surface; skin light pink or flesh color. Reference: Vick's Floral Guide, 1889, p. 85.

Early Mayflower. Originated by E. S. Brownell, Essex Junction, Vt., in 1877; claimed to be a seedling of Snowflake crossed with Peachblow. Offered by B. K. Bliss & Sons and D. M. Ferry & Co. in 1883.

Description.—Ripens with Early Rose. Vines strong, healthy, vigorous, and with a spreading habit of growth. Tubers medium size, oval, slightly flattened; eyes few, small, and nearly even with the surface; skin smooth, light lemon color, well covered with fine netting (Thorburn says, "white, sometimes strongly shading to russet"); flesh white. References: Rural New Yorker, vol. 42, 1883, p. 117; J. M. Thorburn & Co.'s seed catalogue, 1884, p. 8; Henry A. Dreer's Garden Calendar, 1886, p. 24.

Early Michigan. (Group 3.) Originated by Martin Bovee, Northville, Mich.; parentage not given. Introduced by H. N. Hammond in 1895. Reference: H. N. Hammond Seed Co.'s catalogue, 1900, p. 3.

Description.—Season early; vines of medium vigor. Reference: Rural New Yorker, vol. 55, 1896, p. 210. H. N. Hammond says, "This is the second year I have offered it. Tubers snowy white when dug; flesh snowy white." References: H. N. Hammond Seed Co.'s catalogue, 1897, p. 2; 1900, p. 3. An oblong, white, handsome potato with eyes on the surface; skin clear white. Among the very earliest sorts. Reference: J. J. H. Gregory's seed catalogue, 1899, p. 5. It resembles Early Ohio in general appearance, with this difference, that the flesh and skin are white. Reference: Currie Bros.' Farm and Garden Annual, 1902, p. 25.

Note.—As observed by the writer, the skin of some of the tubers has a pinkish tinge around the bud-eye cluster, similar to that in the Early White Albino.

Early Norther. (Group 4, section 1.) Originated by G. W. P. Jerrard, Caribou, Me., in 1887; claimed to be a seedling of Early Rose. Introduced by Jerrard in 1892.

Description. In season of ripening, shape, and color it closely duplicates its parent, though it outyields that variety two to one. Eyes few and shallow. Ref-

erences: G. W. P. Jerrard Co.'s catalogue, 1894, p. 4; J. J. H. Gregory's seed catalogue, 1894, p. 4; Peter Henderson & Co.'s seed catalogue, 1894, p. 15.

Early Ohio. (Group 5.) Originated by Alfred Reese in 1871; claimed to be a seedling of Early Rose. Introduced by J. J. H. Gregory in 1875.

Description.—Grown side by side with the Early Rose, it proved several days earlier and its yield a third greater. While similar to the Early Rose in color, it is quite distinct in shape, being round-oblong instead of oval-oblong, and can be easily distinguished; eyes about as numerous as those of the parent, brows rather more prominent; on the largest specimens the clusters of eyes at the seed end are located slightly to one side of the longer axis. Reference: J. J. H. Gregory's seed catalogue, 1875, p. 47.

Early Ohio, Jr. (Group 5.) Origin not given.

Description.—A most valuable addition to our extra-early varieties. Resembles Early Ohio, but is more nearly round and a larger yielder. Tubers oval-oblong, round at the seed end, with full eyes almost even with the surface. Reference: Northrup, Braslan, Goodwin Co.'s seed catalogue, 1896, p. 38.

Early Peachblow. (Group 11.) Origin not given.

Description.—Season very early, but a poor cropper. A new variety and half brother of Bliss's Triumph, the only practical difference between the two being the color, which is creamy white, with occasional russet splotches, pink eyes, and purple splotches on the skin. Reference: Successful Farming, February, 1910, p. 40.

Early Peachblow, Hall's. (Group 11.) Originated by B. P. Hall, of Vermont; claimed to be a seedling of the famous Jersey Peachblow. Introduced by J. J. H. Gregory in 1883.

Description.—Season early; six weeks earlier than the old Peachblow. Tubers have deep eyes; skin buff colored with rosy purple splotches and bands. References: J. J. H. Gregory's seed catalogue, 1883, inside of front cover; Rural New Yorker, vol. 43, 1884, p. 130; Pharo's Chart, 1888.

Early Pearl. Origin not known. Introduced by J. A. Everitt & Co., Watsontown, Pa.

Description.—Tubers cylindrical, medium long, not much flattened; eyes medium in number and prominence; skin buff white. Reference: Rural New Yorker, vol. 45, 1886, pp. 218, 219.

Early Petoskey. (Group 1.) Origin not given. Introduced by Darling & Beahan in 1905.

Description.—Season early. Vines strong and healthy; flowers light purple and borne in great profusion. Tubers round, slightly flattened; eyes few and shallow; skin pure white, smooth, glossy, and very thin; flesh solid and white. Reference: Darling & Beahan's seed catalogue, 1909, p. 51.

Early Pinkeye. Synonym of DYKEMAN.

Early Prosperity. Origin not known. Introduced by the Iowa Seed Co. in 1908.

Description.—Extra-early variety of strong, vigorous, healthy growth. Tubers oval, slightly flattened, smooth; eyes few; skin white. Reference: Iowa Seed Co.'s catalogue, 1908, p. 26.

Early Puritan. (Group 3.) Originated by E. L. Coy, Hebron, N. Y., in 1882; claimed to be a seedling of Beauty of Hebron. Introduced by Peter Henderson & Co. in 1888.

Description.—Ripens as early as Early Rose. Vines vigorous, with an upright habit of growth. Tubers medium long, not flattened, tapering at the ends; eyes large, even with the surface; skin and flesh pure white. References: Peter Henderson & Co.'s seed catalogue, 1889, p. 8; W. H. Maule's seed catalogue, 1889,

p. 12; Rural New Yorker, vol. 46, 1887, p. 735; Frank Ford & Sons' seed catalogue, 1889, p. 24.

Early Red Rose, Extra. See EXTRA-EARLY RED ROSE.

Early Rose. (Group 4, section 1.) Originated by Albert Bresee, Hubbardton, Vt., in 1861; claimed to be a seedling of Garnet Chili. Introduced in a limited way in 1867 by D. S. Heffron, of Utica, N. Y.; introduced to the public by B. K. Bliss & Sons in 1868.

Description.—Season early; matures about 10 days earlier than Early Goodrich. Vines stout, erect, stalks of medium height; large leaves; flowers freely, bears no balls. Tubers quite smooth, nearly cylindrical, varying to flattish at the center, tapering gradually toward each end; eyes shallow, but sharp and strongly marked; skin thin, tough, of a dull blush color; flesh white, solid, brittle, rarely hollow. References: B. K. Bliss & Sons' abridged catalogue and gardener's almanac, 1869, p. 58; Country Gentleman, vol. 30, 1867, p. 410; American Agriculturist, vol. 27, 1868, p. 10; Rural New Yorker, vol. 19, 1868, p. 103.

Early Rose, Improved. Synonym of EARLY ROSER.

Early Rose, Old. See OLD EARLY ROSE.

Early Roser. Synonym, *Improved Early Rose*. (Group 4, section 1.) Originated by Mr. Roser; claimed to be a seedling of Early Rose.

Description.—Season early. Tubers quite long, with numerous eyes and of the Rose color. Like the Early Rose in its best days. Reference: Joseph Harris Co.'s seed catalogue, 1907, p. 38.

Early Russet. Synonym, *Henderson's Early Russet*. Originated in Maine; claimed to be a 1903 seedling from two famous early varieties.

Description.—Season very early; large enough for cooking in 8 weeks after planting and fully matured in 9 to 10 weeks. Vines of upright, compact growth, with large, healthy foliage. Tubers roundish oval, very uniform in shape and size; eyes shallow; skin creamy buff with golden-russet netting; flesh white. Reference: Peter Henderson & Co.'s seed catalogue, 1908, p. 42.

Early Russet, Henderson's. Synonym of EARLY RUSSET.

Early Sebec. Synonym, *Boston Market*. Thought to be a seedling of Jackson White.

Description.—Season early; keeps late. Tubers large; skin white, nearly smooth; flesh white, fine grained. Preferred by Boston gardeners to any other variety. Reference: Washburn's Amateur Cultivator's Guide, 1868, p. 133.

Early Shaw. Synonym, *Early Henry*. Originated by Bradley Shaw, Dover Township, Mich.; claimed to be a seedling of the Mercer. Introduced prior to 1864.

Description.—For earliness and excellence we have not seen its equal. Vines are not very vigorous, nor are the yields large. Tubers very uniform in size, oval, flattened; skin wholly or partly covered with a characteristic roughness. This variety should not be confused with the English variety of the same name. References: American Agriculturist, vol. 24, 1865, pp. 44, 141; Cultivator and Country Gentleman, vol. 34, 1869, p. 39.

Early Six Weeks. Synonyms, *Six Weeks* and *Early Six Weeks Market*. (Group 5.) Originated in Ohio in 1885; thought to be a seedling of Early Ohio. Introduced by J. A. Everitt in 1890.

Description.—Reaches maturity in 72 days. Tubers oblong to round, medium to large; eyes shallow; skin light flesh color; flesh white. References: J. A. Everitt's seed catalogue, 1890; 1895, pp. 57 and 58; 1904, pp. 130 and 131; J. J. H. Gregory's seed catalogue, 1892, p. 3; Rural New Yorker, vol. 51, 1892, p. 202; John A. Salzer Seed Co.'s catalogue, 1895, p. 133.

Early Six Weeks Market. Synonym of EARLY SIX WEEKS.

Early Standard, Dreer's. (Group 1.) Origin not given. Introduced by H. A. Dreer.

Description.—Extremely early, maturing one week in advance of Bovee. Vines dwarf, compact, strong, and healthy. Tubers good size, roundish; eyes few; skin white, smooth; flesh pure white. References: H. A. Dreer's Garden Book, 1904, p. 9; 1914, p. 35.

Note.—Very similar to Irish Cobbler and may possibly be identical.

Early Sunlight. Synonym of SUNLIGHT.

Early Surprise. Synonym, *Page's Extra-Early Surprise*. Origin not given. Introduced by the Page Seed Co. in 1901.

Description. Season extra early, much earlier than Early Rose, Early Ohio, or Early Michigan, and more productive. Tubers oblong, uniformly of good size, eyes well set on the surface; skin slightly shaded with pink; flesh white, remarkably fine grained. References: Page Seed Co.'s catalogue, 1901, p. 16; 1905, p. 24.

Early Surprise. Originated by G. W. P. Jerrard, Caribou, Me., in 1900. Claimed to be a seedling; parentage not given. Introduced by the Jerrard Co. in 1902 in a limited way.

Description.—Earlier than Early Harvest or New Queen. Vigorous, upright, with bushy top. Tubers nearly round; eyes shallow; skin white; flesh white. Reference: G. W. P. Jerrard Co.'s catalogue, 1903, p. 2.

Note.—It is evident that this variety is not identical with the preceding one of the same name. The description tallies very closely with that of Irish Cobbler.

Early Telephone. Originated in 1876 by E. S. Brownell, Essex Junction, Vt.; claimed to be a seedling of Snowflake crossed with Peachblow.

Description.—Ripens early, matures with Early Rose. Vines vigorous and productive. Tubers oval to oblong and somewhat flattened; eyes few and smooth; skin white, shading to russet; flesh white; flavor excellent. References: W. A. Burpee's Farm Annual, 1883, p. 36; D. M. Ferry & Co.'s catalogue, 1883, p. 164; Vaughan's Corn and Potato Manual, 1884, p. 12; B. K. Bliss & Sons' potato catalogue, 1883, p. 15.

Early Thoroughbred. (Group 4, section 1.) Originated in 1846; parentage not known. Introduced by W. H. Maule in 1896.

Description.—Season early. Vines of medium vigor, somewhat spreading; flowers white. Tubers oblong, twice as long as broad, cylindrical, shapely; eyes even with the surface; skin flesh color; flesh snowy white. References: W. H. Maule's seed catalogue, 1896, p. 7; Rural New Yorker, vol. 56, 1897, p. 7; Johnson & Stokes' Garden & Farm Manual, 1897, p. 12.

Early Vermont. Synonym of EXTRA-EARLY VERMONT.

Early Victor. Synonym of VICKTOR.

Early Walters. (Group 4, section 1.) Originated by W. O. Walters, Petoskey, Mich.

Description.—A first early variety. Vines tall and broad, with strong stalks and abundant, coarse, light-colored foliage. Tubers rather long, oval; eyes shallow; skin light red or amber, smooth; flesh very white. Reference: Darling & Beahan's seed catalogue, 1909, p. 49.

Early Wendell. Synonym of WENDELL.

Early White Albino. (See also EARLY ALBINO.) Origin not given.

Description.—Season very early and a good cropper. Vines grow erect. Tubers oblong to cylindrical, with tendency to vary widely from the type; skin and flesh

extremely white. Listed as a new variety by the Johnson Seed Potato Co. in its 1911 catalogue, p. 3.

Note.—The above description regarding color of skin is somewhat misleading, as many of the tubers show light flesh or pink splashes around the eyes, particularly around the bud-eye cluster.

Early White Triumph. Synonym of WHITE TRIUMPH.

Early Wisconsin. Originated in 1884 in Columbia County, Wis.; claimed to be a seedling of Early Ohio crossed with Snowflake. Introduced by J. O. Borst, Princeton, Wis.

Description.—According to Borst, this variety is chiefly valuable on account of its extreme earliness and its fine table qualities. Tubers remarkably smooth and uniform in shape; skin light rose colored or nearly flesh color, shading to pink about the eyes. References: L. L. Olds's catalogue of seed potatoes, 1891, pp. 6 and 7; Rural New Yorker, vol. 51, 1892, p. 202.

Note.—Vaughan says, "Originated with a well-known grower at Fort Atkinson, Wis. Skin white." Reference: Vaughan's seed catalogue, 1904, p. 8. Vaughan probably meant Thomas Craine.

Empire State. (Group 8, section 1.) Originated by E. L. Coy, Hebron, N. Y., in 1881; claimed to be an inbred seedling of White Elephant. Introduced by W. A. Burpee in 1885. References: W. A. Burpee's Farm Annual, 1885, p. 16; I. F. Tillinghast's catalogue, 1885, p. 12.

Description.—Season medium late. "The most productive main-crop potato ever introduced; vines rank, vigorous. Eyes shallow, but strong; skin white, smooth; flesh pure, snowy white." Reference: Rural New Yorker, vol. 44, 1885, p. 265. Van Ornam says: "Potatoes oblong in shape, large size, smooth, and very handsome." Reference: Van Ornam's "Potatoes for Profit," 1896, p. 79.

Note.—Notice that the tubers as represented in the figure accompanying the reference in the Rural New Yorker are cylindrical in shape.

Endurance, Mills's. Originated by F. B. Mills, Rose Hill, N. Y.; claimed to be a seedling of Green Mountain. Introduced by Mills in 1894.

Description.—Vines erect and vigorous. Tubers large and of even size; eyes shallow; skin white; flesh white. References: F. B. Mills's catalogue, 1895, p. 19; H. N. Hammond Seed Co.'s catalogue, 1897, p. 18.

Enormous. Originated by A. E. Manum, Bristol, Vt.; claimed to be a seedling of State of Maine crossed with White Star. First introduced under the name of North Star, but on account of the preemption of that name by a previous variety the name was changed to Enormous.

Ensign Bagley. Synonym of CLARK'S PRIDE.

Eureka. Origin not given. Introduced by Frank Ford & Sons in 1891 as a new variety. Similar in many respects to Brownell's Eureka.

Description.—Season medium. Vines remarkably vigorous, very productive. Tubers large to very large, long, a little larger at the stem end, oval or nearly round; eyes numerous, shallow; skin white, much russeted. References: Frank Ford & Sons' seed catalogue, 1891, p. 34; 1892, p. 33. The Rural New Yorker says, "Intermediate; tubers cylindrical, shapely, and inclined to be too long; eyes few; skin buff white." Reference: Rural New Yorker, vol. 51, 1892, p. 859.

Note.—This potato in many respects very closely resembles Brownell's Eureka, and it is rather questionable whether it is really a new variety.

Eureka, Brownell's. Originated by E. S. Brownell, Essex Junction, Vt., in 1871; claimed to be a seedling of Excelsior crossed with White Peachblow. Introduced in 1875.

Description.—Season early or medium. Vines medium size, strong and vigorous, lightish green foliage. Tubers medium size, elongate-oval, somewhat flattened,

very symmetrical and smooth; eyes few, shallow, and quite small; skin white; flesh white. References: *Cultivator and Country Gentleman*, vol. 39, 1874, p. 580; B. K. Bliss & Sons' potato catalogue, 1877, p. 14; 1878, p. 27; Henry A. Dreer's *Garden Calendar*, 1875, p. 35.

Note.—It is evident that this variety is entirely different from Early or Extra-Early Eureka, which we now class as identical with Irish Cobbler.

Eureka, Extra-Early. (Group 1.) Originated by George R. Pedrick, of New Jersey, in 1895; claimed to be a sport of Early Morn. W. H. Maule says: "A chance hill found in a field of Early Morn potatoes during the season of 1895. In looking over the field a single plant was noticed which died while all of the others were green." Introduced jointly by W. A. Burpee and W. H. Maule in 1901. Reference: W. H. Maule's seed catalogue, 1901, p. 28.

Description.—An extra-early variety; as early as or earlier than any other potato under cultivation. Vines dwarf, compact, die down as soon as the tubers are ripened and never make any second growth; foliage dark green. Tubers quite broad, shortened-oblong, thick; eyes few, shallow; skin very smooth and of a pure, snowy white; flesh white. References: W. A. Burpee's *Farm Annual*, 1901, p. 29; 1905, pp. 104 and 105; W. H. Maule's seed catalogue, 1901, p. 28.

Note.—The above description answers every requirement of the Irish Cobbler, and it would appear that they are identical.

Everitt. Originated by O. H. Alexander, Charlotte, Vt.; parentage not known. Reference: *Rural New Yorker*, vol. 47, 1888, p. 353.

Description.—Season medium early. Vines rather short, but stout and vigorous. Tubers long, round, or oval; eyes numerous, shallow; skin bright, light red, thickly netted. Reference: Frank Ford & Sons' seed catalogue, 1889, p. 26. L. L. Olds says, "It is nearly but not quite so early as Sunrise and Ohio." References: L. L. Olds's catalogue of seed potatoes, 1891, p. 5; *Rural New Yorker*, vol. 45, 1886, p. 150 (fig. 95).

Excelsior. Originated by B. B. Whiting, Hillsboro County, N. H., in 1861; claimed to be a seedling of old State of Maine. Pharo's chart represents it as a seedling of Early Goodrich. H. P. Closson, Thetford, Vt., says "Excelsior is a seedling of the State of Maine." Reference: H. P. Closson's descriptive catalogue, 1870, p. 12. Introduced by J. J. H. Gregory about 1868.

Description.—Season late. Vines short, very stocky, almost bushy. Tubers nearly round, medium size; eyes prominent; skin white, thin, smooth. References: J. J. H. Gregory's seed catalogue, 1869, p. 21; 1872, p. 34; 1883, inside of front cover. (See Early Peachblow, Hall's.)

Excelsior, Early. See EARLY EXCELSIOR.

Extra Early, Burpee's. Originated by F. B. Van Ornam, Lewis, Cass Co., Iowa; claimed to be a seedling of the Early Rose. Introduced by W. A. Burpee in 1890.

Description.—Season early. "Its claim to being from 10 days to 2 weeks earlier than Early Rose, Early Puritan, Polaris, etc., and 1 week earlier than Early Ohio has been fully substantiated." Reference: Van Ornam's "Potatoes for Profit," 1896, p. 73.

Extra-Early Eureka. See EUREKA, EXTRA-EARLY.

Extra-Early Fillbasket. See FILLBASKET, EXTRA-EARLY.

Extra-Early Peachblow. See PEACHBLOW, EXTRA-EARLY.

Extra-Early Red Rose. (Group 4, section 3.) Thought by its originator to be a seedling of Early Rose and Early Ohio. Reference: W. H. Maule's seed catalogue, 1902, p. 80.

Description.—Season medium or second early. Vines large, vigorous, healthy, medium compact and erect in habit of growth; stems freely branched, winged,

dark green, slightly tinged with purple; leaves large, long, broad, smooth, flat, and medium dark green; flowers purple. Tubers round-oblong to oval, somewhat flattened; eyes numerous, rather small, medium in depth, pink to reddish in color; skin dull red. Base and internodes of sprouts are pink; tips pink to purple.

Extra Early, Somers'. (Group 4, section 1.) Originated by A. N. Somers, Montague, Mass.; claimed to be a seedling of Early Rose crossed with Delaware.

Description.—Claimed by originator to be three weeks earlier than any other variety. Tubers bear some resemblance in both color and shape to the Early Rose, but are neither as long nor as deep colored. References: Letter of A. N. Somers to the writer, September 14, 1908; Springfield Republican, April 11, 1909.

Note.—The writer's experience shows it to be no earlier than the Early Rose and much later than Irish Cobbler, Triumph, Noroton Beauty, etc.

Extra-Early Surprise, Page's. Synonym of EARLY SURPRISE.

Extra-Early Vermont. See VERMONT, EXTRA-EARLY.

Extra-Early White Rose. See WHITE ROSE, EXTRA-EARLY.

Farmer. Synonym, *Farmer Hastings*. (Group 8, section 1.) Origin not known.

Description.—Late maturing, productive, strong, vigorous. Tubers of good size and shape; skin white. Claimed to be remarkably resistant to blight and drought. Reference: John Lewis Childs's catalogue, 1911.

Farmer Hastings. Synonym of FARMER.

Farmer's Alliance. Originated in 1888; claimed to be a seedling of State of Maine crossed with Early Vermont. Introduced by D. Landreth & Sons in 1892.

Description.—An early variety with vigorous, deep-green foliage. Tubers about the same shape as those of the Early Vermont; flesh white, fine grained. Reference: D. Landreth & Sons' catalogue, 1892, p. 40.

Faultless. Originated by W. E. Johnson, Richmond, Me., in 1903; claimed to be a seedling of Green Mountain crossed with Norcross. Introduced by the Johnson Seed Potato Co. in 1908.

Description.—Vines upright; foliage dark green. Tubers slightly elongated; eyes very shallow; skin creamy, somewhat netted. Reference: Charles F. Saul's seed catalogue, 1908, p. 42.

Fillbasket, Extra-Early. (Group 4, section 1.) Claimed to be a seedling of Snow-ball crossed with Quick Crop.

Description.—Season early; a remarkably quick grower. Tubers smooth and full, with no points or projections; sufficiently elongated to make a good baker; skin somewhat resembles that of the Prince Edward Island Rose in color; flesh pure white. Reference: Moore & Simon's catalogue, 1906, p. 41.

Flourball, Johnson's. (Group 1.) Originated in northern New York.

Description.—Season early; earlier than Early Rose. Tubers almost round; skin and flesh pure white. Reference: Johnson Seed Potato Co.'s catalogue, 1910, p. 47.

Fortune, Early. See EARLY FORTUNE.

Freeman. (Group 8, section 1.) Originated by Freeman in 1885; claimed to be a seedling of Silver Tip. Introduced by W. H. Maule in 1891.

Description.—Season very early. Tubers oval; skin russet; eyes shallow; flesh very white and fine grained. References: W. H. Maule's seed catalogue, 1891, p. 61; 1893, p. 73; J. J. H. Gregory's seed catalogue, 1894, p. 4.

Note.—This description of the tubers is very misleading; also the assertion as to earliness. The Freeman, as now known, is medium late, tubers oblong and somewhat flattened, skin dull, creamy white or light buff color.

Garfield. Originated by O. H. Alexander, Charlotte, Vt.; claimed to be a seedling of Early Vermont crossed with Excelsior. Introduced by D. Landreth & Sons in 1883.

Description.—Season later than that of the Vermont; more productive. Vines stocky. Tubers uniformly large, larger than Vermont, slightly flattened, compact in hill; color of skin resembling that of Excelsior. References: J. C. Vaughan's Corn and Potato Manual, 1884, p. 9; Landreth's Companion for the Garden and Farm, 1884, p. 55.

Garnet Chili. Originated by C. E. Goodrich, Utica, N. Y., in 1853; claimed to be a seedling of Rough Purple Chili. Introduced by Goodrich in 1857.

Description.—Season late. Goodrich says, "Vines tall and stout like the parent, remaining erect until nearly ripe. Vines and leaves very light green; flowers numerous and persistent, usually white and showy, occasionally, especially for the last two summers, inclining to Peachblow red and a few even to pale lilac. Rarely bears seed balls unless planted late in June. In this case they set freely in the cool weather of September, but do not mature. I have never seen more than 100 ripe balls on this crop, though examining many acres for them. Tubers medium size, round to longish; eyes of moderate depth; skin brick red; flesh moderately white; late maturing." References: Country Gentleman, vol. 22, 1863, p. 155; American Agriculturist, vol. 21, 1862, p. 230.

Note.—As now known, the flowers are reddish lilac. The variety now grown in Bermuda under the name of Garnet Chili has round-oblong or short-cylindrical tubers with numerous eyes. The variety grown under this name by the Department of Agriculture has roundish to short-oblong tubers with blunt ends.

Gem of Aroostook. (Group 6.) Originated by G. W. P. Jerrard, Caribou, Me., in 1892; claimed to be a seedling of New Queen. Introduced by Jerrard in 1898.

Description.—Season medium; about a week later than New Queen. Vines robust, healthy, half upright; foliage medium green; flowers white with yellow centers. Tubers elongate-oval, flattened; skin light magenta pink in Colorado and pink in northwestern Washington, variable with different soils and localities. References: G. W. P. Jerrard Co.'s catalogue, 1898, p. 2; 1899, p. 2.

Gold Coin. (Group 8, section 1.) Originated by Gideon T. Safford, North Bennington, Vt. Introduced by W. A. Burpee in 1903.

Description.—Vines strong, healthy, with luxurious dark-green foliage. Tubers slightly oblong, rather broad, quite thick, ends slightly rounded; eyes small; skin thin, smooth, glossy, and of a light golden tint; flesh pearly white. Reference: W. A. Burpee's Farm Annual, 1903, pp. 26-29.

Golden Russet, Olds's. (Group 7, section 2.) Originated in Clinton, Wis.; claimed to be a chance seedling from a field of Early Ohio, but not at all like that variety.

Description.—Season medium. Tubers rather long and smooth; eyes even with the surface; skin white, completely covered with a very thick netting, making it a decided russet. References: L. L. Olds's seed catalogue, 1912, p. 29; John A. Salzer Seed Co.'s catalogue, 1912, p. 122.

Note.—Evidently they are confusing a sport with a seedling.

Goodrich, Early. See EARLY GOODRICH.

Granite State. Originated by B. B. Whiting, Hillsboro County, N. H., in 1861; claimed to be a seedling raised at the same time and by the same person as Excelsior. Introduced by J. J. H. Gregory.

Description.—Season early; earlier than Excelsior and tubers are larger and longer. Remarkably bushy in habit of growth. References: J. J. H. Gregory's seed catalogue, 1870, p. 32; 1871, p. 28.

Great Divide. (Group 9, section 1.) Originated by F. B. Van Ornam, Lewis, Cass Co., Iowa, in 1887. Claimed to be a seedling of Early Ohio crossed with old California. Introduced by W. A. Burpee in 1894.

Description.—Season medium to late. Vines stout, erect, branching direct from the main stem; leaves abundant, dark green. Tubers oblong, round; eyes numerous, shallow; skin very white; flesh very white. References: W. A. Burpee's Farm Annual, 1894, pp. 30–31; Van Ornam's "Potatoes for Profit," 1896, p. 76.

Great Eastern. Originated by E. S. Brownell, Essex Junction, Vt., in 1880; claimed to be a seedling of Excelsior crossed with Peachblow. Introduced by J. M. Thorburn & Co. in 1885.

Description.—Season medium early. Vines medium height, stocky and healthy; leaves dark green and free from disease. Tubers oval and somewhat flattened, free from prongs; eyes few and shallow; skin white; flesh white. References: Rural New Yorker, vol. 44, 1885, p. 265; American Garden, vol. 6, 1885, p. 22; J. M. Thorburn & Co.'s seed catalogue, 1886, p. 32.

Green Mountain. (Group 8, section 1.) Originated by O. H. Alexander, Charlotte, Vt., in 1878; claimed to be a seedling from a cross between Dunmore and Excelsior. Introduced by J. A. Everitt & Co. in 1885.

Description.—Season medium late. Vines vigorous, foliage deep green. Tubers short and chunky, flattened, and not very regular; eyes sometimes slightly, sometimes considerably depressed; skin nearly white; flesh white, fine grained. References: Rural New Yorker, vol. 43, 1884, p. 729; American Garden, vol. 6, 1885, p. 102; Cultivator and Country Gentleman, vol. 51, 1886, p. 280; J. A. Everitt's seed catalogue, 1895, p. 60; Angell Seed Co.'s Manual, 1899, p. 20.

Note.—The following description seems to represent more adequately the Green Mountain at the present time: Vines vigorous, healthy, considerably branched; foliage heavy, medium green; stems light green; flowers abundant, white. Tubers large, short-oblong to oblong, broad, flattened; eyes medium in number and size, shallow to medium in depth; skin creamy white or buff white, occasionally splashed with russet toward seed end, generally well netted.

Green Mountain, Jr. (Group 8, section 1.) Originated by W. E. Johnson, Richmond, Me., in 1905; claimed to be an inbred Green Mountain (that is, from a seed ball grown on Green Mountain pollinized with Green Mountain). The originator says, "Practically a thoroughbred or purebred." Introduced by the Johnson Seed Potato Co.

Description.—Season late. Vines much branched and vigorous; leaves broad, dark green; blossoms white with yellow centers; tubers round to oblong, somewhat flattened; eyes shallow; skin a trifle whiter than that of its parent and more netted. Sprouts white and stubby in the spring and do not grow very long. Reference: Johnson Seed Potato Co.'s catalogue, 1911, p. 5.

Note.—So far as the writer's experience with this variety goes, it does not appear to possess qualities superior to those of its parent.

Gurney's White Harvest. See WHITE HARVEST, GURNEY'S.

Hall's Early Peachblow. See EARLY PEACHBLOW, HALL'S.

Hampden Beauty. Ross Bros. and Frank Ford & Sons claim that this variety originated in Vermont, while Aaron E. Low says that it originated in Hampden County, Mass. Its name would indicate that the latter assumption is correct. Claimed to be a sport of Beauty of Hebron. Introduced as a novelty in 1886.

Description.—Season early. Vines stocky and thrifty. Tubers oblong-oval, medium to large; eyes numerous (A. W. Livingston says "few"), shallow; skin white, finely netted, smooth; flesh white, solid. References: A. W. Livingston's

seed catalogue, 1888, p. 47; Frank Ford & Sons' catalogue, 1890, p. 28; Aaron E. Low's seed catalogue, 1889 and 1891; Ross Bros.' catalogue, 1898, p. 11; Parker & Wood's catalogue, 1891, p. 111; Rural New Yorker, vol. 51, 1892, p. 859.

Harbinger. (Group 6.) Originated by G. W. P. Jerrard, Caribou, Me., in 1886; claimed to be a seedling of New Queen. Introduced by Jerrard in 1890.

Description.—Strong, robust grower; leaves large, dark green; flowers white. Tubers large, long, and rather flat; eyes not numerous, quite even with the surface; skin light flesh color, smooth, red in the cavity of the eyes. References: Rural New Yorker, vol. 49, 1890, p. 150; Frank Ford & Sons' catalogue, 1891, p. 34; 1893, p. 38; Cole's Garden Annual, 1892, p. 48.

Harvest, Early. See EARLY HARVEST.

Henderson's Early Russet. Synonym of EARLY RUSSET.

Henry, Early. Synonym of EARLY SHAW.

Honeoye Rose. (Group 2.) Claimed to be a seedling of Victor Rose. Introduced by E. F. Dibble, Honeoye Falls, N. Y., in 1896.

Description.—An early, strong-growing, heavy-yielding variety. Tubers pale pink; skin around the eyes like the eyebrows; color deepens into a deep but brilliant red. References: E. F. Dibble's farm seed catalogue, 1896; H. N. Hammond Seed Co.'s catalogue, 1897, p. 12. The Rural New Yorker says, "Medium vigor. Stems green; flowers purplish. Tubers irregular in shape; skin pinkish buff." Reference: Rural New Yorker, vol. 55, 1896, p. 231.

Note.—This variety seems to be identical with Noroton Beauty, or Quick Lunch.

Hoosier, Late. Synonym of McCORMICK.

Houlton Rose. (Group 4, section 1.) Originated in Houlton, Me. Reference: Buist's Garden Guide, 1894, p. 102.

Note.—Simply an early strain of Early Rose.

Hunt, Early. Synonym of TRIUMPH.

Hybrid, Rhind's. See RHIND'S HYBRID.

Idaho Rural. (Group 8, section 2.) Origin not given.

Description.—See Charles Downing and Rural New Yorker No. 2.

Note.—As observed by the writer, the name Idaho Rural is used rather indiscriminately. The variety which is generally regarded as the true Rural is probably the Charles Downing. Another variety which is grown as Idaho Rural in the West is a member of the Rural group.

Ideal. Claimed to be a seedling of Jersey Peachblow.

Description.—Ripens in midseason. Vines large, stocky, upright in early part of season, but of branching, spreading habit later. Tubers ovate, rather truncate, much flattened; eyes medium as to number and prominence; skin buff to delicate pink russet. References: The American Horticulturist, 1891, p. 197; Rural New Yorker, vol. 50, 1891, p. 102; Peter Henderson & Co.'s seed catalogue, 1895, p. 18.

Improved Beauty of Hebron. See BEAUTY OF HEBRON, IMPROVED.

Improved Early Rose. Synonym of EARLY ROSER.

Improved Manistee. Synonym of EARLY MANISTEE.

Improved Peachblow. See PEACHBLOW, IMPROVED.

Improved Peachblow, Nichol's New. See PEACHBLOW, NICHOL'S NEW IMPROVED.

Irish Cobbler. (Group 1.) Origin not known; claimed by some leading seedsmen to have been first grown by an Irish shoemaker of Marblehead, Mass.

Description.—Season extra early. Gregory says, "Similar or identical with Eureka." Tubers nearly round, large; eyes good; skin russet, finely netted; flesh white. References: Vaughan's seed catalogue, 1895, p. 23; J. J. H. Gregory's seed catalogue, 1899, p. 4; 1907, p. 27.

Note.—In the writer's opinion the Irish Cobbler is simply a strain of the Early Eureka, and at the present time the two are so hopelessly mixed up as to be indistinguishable. There are some growers and seedsmen, however, who seem to believe that the two varieties are distinct entities.

Jackson White. (Group 9, section 1.) Claimed to be a seedling of the Carter and to have originated in Maine.

Description.—Tubers more irregular in form than those of the Early Cottage, Early Shaw, and Early Samaritan; eyes more deeply sunken. References: Magazine of Horticulture, vol. 23, 1857, p. 59; Country Gentleman, vol. 14, 1859, p. 107; American Agriculturist, vol. 24, 1865, p. 44. Richard Frotscher says, "It is white, has a great many eyes, and is of very good quality." Reference: Richard Frotscher's Almanac and Garden Manual, 1880, p. 51.

Note.—Thought by some to be identical with Carter.

Jersey Peachblow. Synonyms, *Old Jersey Peachblow*, *Peachblow*. (Group 11.) Originated by Caleb Shepard, of Old Saratoga, N. Y., in 1850. Claimed to be a seedling of the Western Red or Chenango. The two varieties grew side by side, and the seed balls were picked indiscriminately.

Description.—A late-maturing, long-keeping variety. Tubers red skinned, yellow fleshed. References: Magazine of Horticulture, vol. 23, 1857, p. 60; Country Gentleman, vol. 26, 1865, p. 315.

Johnson's Flourball. See FLOURBALL, JOHNSON'S.

Jones Pink-Eyed Seedling. (Group 4, section 3.)

Description.—"We are offering you for the first time a new late potato which we believe has great merits, not only in quality but a very heavy yielder. * * * The tubers are oblong and of good size, very solid, and good keepers. They mature about the same time as New York Rurals or Carman No. 3." Reference: O. S. Jones Seed Co's. catalogue, Sioux Falls, S. Dak., 1912, p. 32.

Joseph. Originated by H. F. Smith, of Vermont, and introduced by him in 1896.

Description.—Season medium. Vines vigorous and healthy. Tubers oval, slightly flattened on two sides; eyes few; skin pinkish; flesh white. References: L. L. Olds's seed catalogue, 1897, p. 5; Joseph Breck & Son's seed catalogue, 1898, p. 15; Frank Ford & Sons' seed catalogue, 1898, p. 43.

Jumbo. Synonym, *Weld's Jumbo*. Originated in western New York. Introduced in 1881.

Description.—Season medium early. Vines vigorous, short jointed compact, deep green. Tubers nearly round, slightly flattened; eyes small; skin white, flesh white. References: B. K. Bliss & Sons' potato catalogue, 1883, p. 10; Peter Henderson & Co.'s seed catalogue, 1883, p. 39; American Garden, vol. 4, 1883; p. 83; Vaughan's Corn and Potato Manual, 1884, p. 13. Ford says, "Season late. Tubers long; eyes numerous, some full, others slightly depressed." Reference: Frank Ford & Son's seed catalogue, 1885, p. 14.

June Eating, Craine's. Originated by Thomas Craine, Fort Atkinson, Wis., in 1884; claimed to be a seedling of Eureka.

Description.—Season very early. Habit of growth and foliage similar to Early Rose. Tubers oblong to long, nearly round, large; skin white, clouded with purple; flesh white. Reference: Frank Ford & Sons' seed catalogue, 1887, p. 17.

Junior Pride. Synonym of WHITE TRIUMPH.

Note.—The variety in the Department of Agriculture collection is not identical with White Triumph as cited in D. Landreth & Sons' catalogue for 1910, p. 74.

Junkie. Originated by Luther Putnam, Cambridge, Vt.

Description.—A late-maturing, heavy-yielding variety. Tubers rather long, flattened, generally tapering at one end; flesh white and of good quality. Reference: Rural New Yorker, vol. 45, 1886, p. 219.

Keeper, Craine's. Originated by Thomas Craine, Fort Atkinson, Wis., in 1883; claimed to be a seedling of Eureka.

Description.—Season medium, ripens last week in August. Vines strong growing and of spreading habit. Tubers round and unusually elongated, very solid; eyes few and shallow; skin white; flesh white and floury when cooked. Reference: Frank Ford & Sons' seed catalogue, 1887, p. 17.

Note.—This variety is entirely distinct from another of the same name now in the variety collection of the Department of Agriculture.

Keystone. (Group 8, section 1.) Originated by H. E. Hopkins, Conneautville, Pa., in 1901; claimed to be a seedling of Carman No. 1.

Description.—Vines bushy rather than tall, not decumbent. Tubers long and slightly tapering; skin white and finely netted; flesh marble white, fine grained, and dry. Reference: Vaughan's seed catalogue, 1911, p. 7.

King of the Earlies. Synonym, *Bresee's No. 4*. Originated by Albert Bresee, Hubbardton, Vt., in 1862; claimed to be a seedling of Garnet Chili. Introduced by J. J. H. Gregory in 1869.

Description.—A week earlier than Early Rose. Vines dwarf, averaging 10 to 12 inches. Tubers large, handsome, roundish, and slightly flattened; eyes small, somewhat pinkish; skin flesh color or dull, pinkish white; flesh white, floury. References: Cultivator and Country Gentleman, vol. 32, 1868, p. 291; B. K. Bliss & Sons' seed catalogue, 1870, p. 80; J. J. H. Gregory's seed catalogue, 1870, p. 31; H. P. Closson's descriptive catalogue, 1870, p. 11.

King of the Earlies, Nichol's. Originated in the Red River Valley; parentage not known. Introduced by the St. Louis Seed Co. in 1905.

Description.—Season very early. Superior to the Early Ohio, which it very much resembles in appearance. Skin thick, pinkish; eyes shallow, fair sized. Reference: St. Louis Seed Co.'s catalogue, 1905, p. 52. The Rural New Yorker says, "Vines of medium vigor and spreading habit; no flowers. Tubers shape of Beauty of Hebron; eyes medium in prominence and number; skin colored like that of Early Rose; flesh white and mealy." Reference: Rural New Yorker, vol. 55, 1896, p. 850.

Knowles's Big Cropper. Synonym of KNOWLES.

Knowles's Big Crop Potato. Synonym of KNOWLES.

Knowles. Synonyms, *Knowles's Big Crop*, *Knowles's Big Cropper*. Originated by B. W. Knowles, Aroostook County, Me. Introduced by J. J. H. Gregory.

Description.—Season medium; ripens about midway between the Irish Cobbler and the Green Mountain. Vines and foliage strong and vigorous. Tubers rather oblong in shape; eyes close to the surface; skin smooth, white; flesh very white. Reference: J. J. H. Gregory's seed catalogue, 1908, p. 6.

La Plata Red. Synonym of LONG RED.

Late Beauty of Hebron. See BEAUTY OF HEBRON, LATE; WHITE ELEPHANT.

Late Blightless. (Group 8, section 1.) Origin not known.

Description.—Season late. Vines large, fairly vigorous, healthy; stems spreading, more or less decumbent, winged, dark green; leaves rather small, smooth, slightly crumpled; flowers white. Tubers large, oblong to elongate-flattened; eyes rather numerous, inclined to be deep; skin white. Sprouts creamy white. On the whole this is an undesirable commercial variety, owing to the coarseness of the tubers. The claim that it is immune to late-blight is not substantiated either in vine or tuber.

Late Hoosier. Synonym of McCORMICK.

Late Ohio. (Group 5.) Originated by Alfred Reese, the originator of the Early Ohio.

Description.—Season second early; a little later than Early Rose. Tubers large, oblong, round; eyes few and very smooth; skin light red or pink. References: J. J. H. Gregory's catalogue, 1880, p. 53; Frank Ford's seed catalogue, 1881, p. 13.

Late Petoskey. Synonym, *Rural Russet*. (Group 9, section 2.) Parentage not given.

Description.—Ripens ten days or two weeks in advance of the Rural New Yorker No. 2. Vines vigorous, with spreading and more or less erect habit of growth; sprouts and stalks very dark purplish green; foliage plentiful and a dark rich color; flowers light purple. Tubers have the general shape of Rural New Yorker No. 2, but they are slightly thicker in cross section; eyes not so deep; skin pure white, like the Rural New Yorker No. 2, but thicker, tougher, and beautifully netted. It is not a russet potato, though it has the general appearance of one. References: Darling & Beahan's seed catalogue, 1908, pp. 15 and 56; 1909, pp. 12 and 53.

Note.—The sprout and stem characters are very similar to, if not identical with, those of Rural New Yorker No. 2. In the experience of the writer, well-grown specimens of the tuber are distinctly russeted.

Late Puritan. Originated by Robert Birch, of Michigan, in 1889; claimed to be a sport of Early Puritan. Introduced by Peter Henderson & Co. in 1891.

Description.—Season late. Identical with the Early Puritan in appearance, color, and quality, but far more productive. Reference: Peter Henderson & Co.'s seed catalogue, 1892, p. 7.

Late Rose. (Group 4, section 1.) Discovered by E. L. Coy, of West Hebron, N. Y., in a field of Early Rose in the autumn of 1869; supposed to be a sport of the Early Rose. Introduced by B. K. Bliss & Sons in the fall of 1871.

Description.—Ripens from two to four weeks later than the Early Rose; much more productive; vines more stocky and upright in growth; leaves thicker and more pointed. Tubers only distinguishable from those of the Early Rose by having a brighter red seed end when first dug. References: B. K. Bliss & Sons' seed catalogue, 1872, p. 80; 1873, p. 141; B. K. Bliss & Sons' potato catalogue, 1874, p. 13; Rural New Yorker, vol. 24, 1871, p. 411; vol. 25, 1872, p. 242.

Late Rose, Campbell's. (Group 4, section 1.) Originated by George W. Campbell, Delaware, Ohio, probably in 1869; claimed to be a seedling of Early Rose. Named Campbell's Late Rose by F. R. Elliott.

Description.—Season late. Tubers much like those of the Early Rose in form; eyes nearly level with the surface, deep, rich, pinkish red with an average of five germs to each eye or cluster of eyes; skin at tuber end (seed end) a rich pale red, at lower end a pinkish white. References: Rural New Yorker, vol. 25, 1872, p. 115; J. M. Thorburn & Co.'s seed catalogue, 1872, p. 19; J. J. H. Gregory's seed catalogue, 1873, p. 45.

Late Snowflake. Originated in northern Vermont in 1875; claimed to be a sport of Snowflake.

Description.—Tubers much more productive and later in maturing than those of Snowflake, but exact counterpart in form, size, color, and general appearance. Reference: B. K. Bliss & Sons' potato catalogue, 1881, p. 15.

Lee's Favorite. (Group 4, section 3.) Originated by G. W. Lee, of Stark County, Ohio, in 1877; claimed to be a seedling of Early Rose. Introduced by Frank Ford in 1883.

Description.—Season two weeks earlier than Early Rose. Tubers similar in form to Early Rose, but distinct in color, being a light flesh shading to pink about the eyes, which are nearly even with the surface. Reference: Frank Ford's seed catalogue, 1883, pp. 13 and 14.

Lightning, Crine's. (Group 4, section 3.) Originated by R. V. Crine, of New Jersey; claimed to be a seedling of Early Ideal crossed with Early Ohio and Early Rose. Introduced by J. M. Thorburn & Co. in 1902.

Description.—Season extra early. Vines vigorous, healthy. Tubers oblong, with flattened ends; skin a remarkably bright rose color, brighter than that of Early Rose. (Thorburn says, "Skin russet colored.") References: Joseph Harris Co.'s Rural Annual, 1903, p. 35; J. M. Thorburn & Co.'s catalogue, 1902, p. 9.

Note.—The Crine's Lightning grown by the Department of Agriculture has a pink skin.

Lily White. (Group 9, section 1.) Originated in Indiana; claimed to be a seedling of Early Rose crossed with White Star.

Description.—Season medium to late; ripens a little later than Early Rose. Tubers smooth and shapely; eyes shallow; skin clear white; flesh white. References: S. Wilson's catalogue, 1894, p. 60; Moore & Simon's catalogue, 1889, p. 32.

Livingston. (Group 4, section 3.) Originated by a Michigan grower in 1893; claimed to be a sport of Seneca Beauty. Introduced by A. W. Livingston & Sons in 1896.

Description.—Tubers are of desirable shape; eyes few and shallow. Reference: A. W. Livingston & Sons' seed catalogue, 1896, p. 12.

Livingston's Banner. See BANNER, LIVINGSTON'S.

Long Island Wonder. (Group 8, section 1.) Origin not given.

Description.—About one week earlier than Green Mountain; a heavier yielder. Tubers same shape and color. Reference: S. D. Woodruff & Sons' seed catalogue, 1913, p. 2.

Note.—It is rather doubtful whether Long Island Wonder is essentially different from Green Mountain.

Long Red. Synonyms, *La Plata Red*, *Spanish*, *Merino*, *Red Mercer*. Origin not known. Supposed to have been introduced into this country from La Plata, South America, about 1806.

Description.—Claimed to be the hardiest potato extant. Reference: Cultivator, vol. 3, 1846, p. 196.

Lookout Mountain. Synonym of McCORMICK.

McCormick. Synonyms, *Late Hoosier*, *Lookout Mountain*. (Group 11.) Originated by the Rev. T. B. McCormick, of Princeton, Ind. Introduced by J. A. Foote, Terre Haute, Ind., about 1882. Reference: Rural New Yorker, vol. 44, 1885, p. 175.

Note.—A variety known as the McCormick is grown to a considerable extent in Maryland and Virginia. It is a late-maturing, strong-growing variety having the Peachblow type of foliage. The tubers are round, oblong, generally with blunt ends and numerous deep-set eyes tinged with carmine; skin flesh or light pink. The variety seems to possess the ability to withstand heat and drought better than any other with which the writer is familiar, but the tubers are of poor quality.

Maggie Murphy. Synonym, *Queen of the West*. Originated by L. Wall; claimed to be a seedling of Wall's Orange. Introduced by James Vick in 1893.

Description.—A late-maturing, strong, vigorous variety. Tubers of the Rose class, large, oblong, round, square at end; eyes very deep; skin delicate pink. References: Vick's Floral Guide, 1893, p. 15; 1894, p. 31; Successful Farming, February, 1910, p. 42.

Magnum Bonum. Season early, a few days later and more productive than Early Rose. Vines vigorous and erect. Tubers nearly round, flattened at the ends; eyes small, pink; skin russet white (Ford says, "Color white, with slight pink

tint at eyes"); flesh white and nutty. References: W. A. Burpee's Farm Annual, 1882, p. 20; Frank Ford's catalogue, 1882, p. 14; B. K. Bliss & Sons' potato catalogue, 1883, p. 11.

Note.—W. A. Burpee says, "An American variety." Frank Ford says, "True American." B. K. Bliss says, "Quite distinct from the English potato of the same name."

Maine Rose. Synonym of EARLY MAINE.

Mammoth Pearl. Originated in Ohio; claimed by Pharo to be a seedling from promiscuously hybridized seed. Introduced about 1879.

Description.—Season medium. Vines short, thick, upright. Tubers large, nearly round; eyes few, but slightly depressed; skin smooth and remarkably white; flesh pearly white. References: B. K. Bliss & Sons' potato catalogue, 1880, p. 15; Frank Ford's seed catalogue, 1881, p. 13; D. M. Ferry & Co.'s catalogue, 1881, p. 48; J. J. H. Gregory's seed catalogue, 1882, p. 55.

Manistee. Synonym of EARLY MANISTEE.

Manistee, Early. See EARLY MANISTEE.

Manistee, Improved. Synonym of EARLY MANISTEE.

Market, Boston. Synonym of EARLY SEBEC.

Market, Early. See EARLY MARKET.

Market, Early Six Weeks. Synonym of EARLY SIX WEEKS.

Matchless. Originated by A. Rand, Shelburne, Vt., in 1875; claimed to be a seedling of Early Rose crossed with White Peachblow. Introduced by B. K. Bliss & Sons in 1880.

Description.—Season late; ripens with the Peerless. Vines upright, of medium height, vigorous, healthy; foliage dark green. Tubers generally round, sometimes oblong, occasionally flattened; skin slightly russeted, pale red except the eyes and seed end, where it is much brighter; flesh pure white, fine grained, and of excellent quality. Reference: B. K. Bliss & Sons' potato catalogue, 1881, p. 13.

Matchless, Corliss's. Originated by T. Corliss, Lockport, N. Y., in 1877; claimed to be a seedling of Humboldt. Introduced by T. Corliss in 1883.

Description.—Season medium; claimed by the originator to be two weeks earlier than the Early Rose. Tubers long, round; eyes numerous, some clusters prominent, others smooth or slightly depressed; skin light pink. Fine quality. References: Cultivator and Country Gentleman, vol. 48, 1883, p. 363; Frank Ford & Son's seed catalogue, 1885, p. 14.

Maxima. (Group 4.) Claimed to be a sport of Lee's Favorite. Introduced by the Ford Seed Co. in 1903.

Description.—Closely resembles Lee's Favorite. Tubers oblong, cross sections oval; eyes rather small and quite even with the surface, not numerous but plenty; skin beautiful pink, shading to darker pink at the seed end, somewhat netted. References: Ford Seed Co.'s catalogue, 1903, p. 56; 1910, p. 44.

Mayflower, Early. See EARLY MAYFLOWER.

Mercer. Synonyms, *Mesha-nock*, *Moshannocks*, *Nephannocks*, *Nishenock*, *Neshannocks*, *Blue Noses*, *Philadelphia*, *Chenango*, and *White Chenango*. Originated on Neshannock Creek, Mercer County, Pa., by J. Gilkey, or Gilkie, about 1811; claimed to be a seedling. James Waugh says, "The potato known as the Mercer or Nishenock was first grown about 47 years ago by John Gilkey, who called it the Nishenock royal potato, and it got the name of Mercer from Bevan Pearson, who carried a few in his saddle to Darby, Pa., from which point they have spread over the United States under the name of Mercer." Reference: Rural New

Yorker, vol. 2, 1858, p. 134. "The true name of this potato should be Gilkie, as it originated from seed sown by John Gilky on the bank of the Neshannock Creek, about five miles above its junction with the Chenango, at Newcastle, Pa." Reference: Farmer's Cabinet, vol. 4, p. 64. (See Cultivator, vol. 10, 1843, p. 190.)

Description.—Season early intermediate. Tubers flat, oblong; eyes numerous, deep purple; skin purple; flesh yellowish. Reference: Rural New Yorker, vol. 43, 1884, p. 235. "Tubers rather long and flat in shape, with numerous eyes; skin white, tinged with a pale purple on the tip end, from which circumstance it has been called by some the Blue Nose. When cut in two a circle of the same color as the tip end is discovered around the center." Reference: Genesee Farmer and Gardener's Journal, vol. 1, 1831, p. 148. "Tubers much like the Long Pinkeye, but generally larger and longer; skin slightly tinged with a reddish or purple color, and when cut streaks of the same color are found running through it." Reference: Farmer's Cabinet, vol. 4, p. 64. (See Cultivator, vol. 10, 1843, p. 190.)

Mercer, Black. Synonym of BLACK CHENANGO.

Mercer, White. See WHITE MERCER.

Merino. Synonym of LONG RED.

Merrill, New. Originated by W. E. Johnson, Richmond, Me., in 1901; claimed to be a seedling of Norcross and Johnson's No. 1. Introduced by the Johnson Seed Potato Co. in 1905.

Description.—Season second early. Immense vine growth, dark green, with large clusters of white blossoms. Tubers round and oblong, similar in shape to those of Early Rose; skin creamy white, well netted, smooth. Reference: W. H. Maule's seed catalogue, 1908, p. 16. Very rapid grower with large, handsome leaves. Tubers oblong; eyes very shallow; skin white, netted. Reference: Johnson Seed Potato Co.'s catalogue, 1905, p. 16.

Meshanock. Synonym of MERCER.

Meshannock, White. Synonym of WHITE MERCER.

Michigan, Early. See EARLY MICHIGAN.

Million Dollar. (Group 9, section 1.) Origin not known. Introduced by the Salzer Seed Co.

Description.—Beautiful white potato, which cooks like a Snowball. References: Salzer Seed Co.'s catalogue, 1900, pp. 115–116; L. L. Olds's seed catalogue, 1902, p. 10.

Mills's Endurance. See ENDURANCE, MILLS'S.

Milwaukee. (Group 6.) Origin not known. Introduced by Currie Bros. in 1892.

Description.—Comes into use fully as early as Early Sunrise, but is more productive. Strongly resembles Crown Jewel, but is of larger size. Reference: L. H. Bailey's "Annals of Horticulture," 1892, p. 191.

Minister. Synonym, *New Minister*. Originated in Aroostook County, Me. Introduced by G. W. P. Jerrard Co. in 1889.

Description.—Season early. Vines large, somewhat spreading, strong, healthy; leaves broad, medium green; immense clusters of light purple blossoms. Tubers medium sized, rather flattened; eyes rather deep; skin magenta interspread with amber; flesh yellowish white, fine grained. References: Parker & Wood's catalogue, 1890, p. 99; Rural New Yorker, vol. 48, 1889, p. 103; G. W. P. Jerrard Co.'s catalogue, 1891, p. 12; 1894, p. 9; John Lewis Childs's catalogue, 1891, p. 16.

Molly Stark. Originated by D. C. Hicks, North Clarendon, Vt. Introduced by Frank Ford & Sons in 1892.

Description.—Season very early; fairly productive. Vines short, but stout. Tubers oval or oblong, flattened oval; eyes numerous, compound, slightly sunken

with a distinct brow; skin very light flesh color, finely netted (The Rural New Yorker says "buff skin"); flesh white and mealy. References: Frank Ford & Sons' seed catalogue, 1892, p. 32; Rural New Yorker, vol. 51, 1892, p. 811.

Money-Maker. (Group 7, section 1.) Origin not given. Introduced by E. F. Dibble.

Description.—Season medium late. Vines and foliage heavy, absolutely and unequivocally blight and drought proof; flowers white; tubers handsome, long, frequently 8 inches and over in length, occasionally flattened; eyes nearly even with the surface; skin white. Reference: E. F. Dibble's farm-seed catalogue, 1895, p. 13. Vines vigorous, upright, flowers white; tubers cylindrical, long, variable in shape; skin light buff. Reference: Rural New Yorker, vol. 56, 1897, p. 38. "This is a long white potato, absolutely blight proof." Reference: Joseph Harris Co.'s Rural Annual, 1898, p. 25:

Note.—Several years' trials of Money-Maker do not justify the claim made for it as a blight and drought resistant variety.

Moreton. Origin not known.

Description.—New, main-crop variety of great vigor. Tubers round, smooth; eyes shallow; skin white. Reference: Joseph Harris Co.'s seed catalogue, 1911, p. 42.

Moshannocks. Synonym of MERCER.

Nephannocks. Synonym of MERCER.

Neshannocks. Synonym of MERCER.

New Blush. Synonym of BLUSH.

New Ideal. (Group 4, section 3.) Origin not known.

Description.—Season medium early. Vines large, stocky, vigorous, upright in early part of season, but with branching, spreading habit later. Tubers have a delicate, pink-russet skin. Reference: Peter Henderson & Co.'s seed catalogue, 1895, p. 18.

New Improved Peachblow, Nichol's. See PEACHBLOW, NICHOL'S NEW IMPROVED.

New Merrill. See MERRILL, NEW.

New Minister. Synonym of MINISTER.

New Queen. (Group 6.) Originated in Washington County, Me.; claimed by G. W. P. Jerrard and J. J. H. Gregory to be a seedling of Beauty of Hebron. Pharo says, "Seedling of Garnet Chili crossed with Beauty of Hebron." Introduced by Jerrard in 1884.

Description.—Season early. Tubers large, handsome, closely resembling those of its parent both in shape and color; flesh pure white. References: J. J. H. Gregory's seed catalogue, 1889, p. 5; G. W. P. Jerrard Co.'s catalogue, 1894, p. 6; 1911, p. 6.

New Scotch Rose. (Group 4, section 3.) Claimed to have been introduced from Scotland.

Description.—Season medium early. Vines large, dense, with strong, stocky stems. Tubers thick, oblong; eyes few, shallow; skin rose colored. Reference: A. G. Aldridge's price-list sheet, 1913.

New Victor. Origin not known. Introduced by the G. W. P. Jerrard Co. in 1907.

Description.—Season early. Vines strong and stocky, tops large and branching; blossoms white. Tubers oval, rather longer than the Green Mountain; eyes even with the surface, some plump and full; skin white. Reference: G. W. P. Jerrard Co.'s catalogue, 1907, p. 3.

New White Mountain. Synonym of WHITE MOUNTAIN.

New White Ohio. Synonym of WHITE OHIO.

New White Peachblow, Thorburn's. See PEACHBLOW, THORBURN'S NEW WHITE.

New Wonderful. (Group 7, section 2.) Introduced in 1899.

Description.—Season late. Vines large, rank, dark; foliage rich green. Tubers round to oblong, very uniform in size; eyes flush with the surface; skin russet, covered with vein work. Reference: S. M. Isbell & Co.'s seed catalogue, 1906, p. 53.

Note.—The shape of the tubers as described in Isbell's catalogue does not coincide with the shape of those grown from stock purchased by the Department of Agriculture from S. M. Isbell & Co. The latter are elongate-cylindrical, and usually slightly flattened.

Nichol's King of the Earlies. See KING OF THE EARLIES, NICHOL'S.

Nichol's New Improved Peachblow. See PEACHBLOW, NICHOL'S NEW IMPROVED.

Nishenock. Synonym of MERCER.

Norcross. (Group 8, section 1.) Originated by Charles Norcross, Litchfield, Me., in 1895; claimed to be a seedling of Early Rose pollenized with Beauty of Hebron. Introduced by the Johnson Seed Potato Co.

Description.—Late maturing. Vines thrifty, upright; leaves large. Tubers large, flat, oval, somewhat blocky in shape; skin white. References: Johnson Seed Potato Co.'s catalogue, 1905, p. 12; 1909, p. 6; Frank S. Platt's Farm and Garden Annual, 1907, p. 6.

Noroton Beauty. (Group 2.) Originated by E. L. Coy, Hebron, N. Y.; claimed to have been obtained from a seedling of old White Peachblow. Introduced by J. M. Thorburn in 1904.

Description.—Matures early; vines short, stocky, branching; stalks purple when they first come up; leaves large and dark green. Tubers round, or nearly so; eyes pinkish; groundwork of skin white, slightly russeted, and splashed more or less with pink. Reference: J. M. Thorburn & Co.'s seed catalogue, 1905, p. 4.

Note.—The Noroton Beauty is, so far as any visible appearance is concerned, identical with Quick Lunch. Both of these varieties were introduced in the same year, the former by J. M. Thorburn, the latter by W. A. Burpee. Noroton Beauty is said to have been originated by E. L. Coy and Quick Lunch by Gideon Safford, of North Bennington, Vt. Both of these originators claim to have had no cognizance of the other's production. Whether this be true or not, the two varieties are practically identical and we believe are now so regarded by the trade.

Norther, Early. See EARLY NORTHER.

Northern Beauty. Claimed to have been an 1889 seedling. Parentage not given.

Description.—A second early variety. Vines vigorous. Tubers medium to large, oblong, and similar to those of Beauty of Hebron or Clark's No. 1; eyes slightly indented; skin and flesh pure white. Reference: Parker & Wood's seed catalogue, 1890, p. 98.

Northern Beauty. (Group 4, section 1.) Originated by G. W. P. Jerrard, Caribou, Aroostook County, Me., in 1894. Introduced by the G. W. P. Jerrard Co. in 1900.

Description.—Strong, upright grower of the Early Rose type, but rather more robust. Tubers not quite as long as those of the Early Rose, a little inclined to be flat. References: G. W. P. Jerrard Co.'s catalogue, 1900, p. 1; 1911, p. 7.

Note.—The tuber description of these two varieties bearing the same name is so meager that it is not possible to determine, in the absence of authentic specimens of each, whether or not they are identical.

Nott's Peachblow. See PEACHBLOW, NOTT'S.

Noxall. (Group 9, section 1.) Origin not known. Introduced by the Wernich Seed Co. in 1911.

Description.—Season late; matures a week earlier than Rural New Yorker No. 2. Tubers of fine appearance and of about the same shape as Rural New Yorker

No. 2, but of better quality; skin white. Reference: Wernich Seed Co.'s catalogue, 1911, p. 43.

Note.—Identical with Rural New Yorker No. 2.

No. 9. (Group 9, section 1.) A selection from Rural New Yorker. Thought to be a superior strain.

Ohio, Early. See EARLY OHIO.

Ohio Junior. Originated by James Vick, Rochester, N. Y., who says: "This new potato originated with us in 1881, and although a chance seedling it is without doubt in some way related to that good old sort, the Early Ohio." L. L. Olds says: "It is the only seedling thus far of the old favorite Early Ohio." Introduced by Vick in 1887.

Description.—Season extra early. Almost identical with the Early Ohio in form and marking of the tubers, habit of growth, etc. Tubers oval-oblong, round at the seed end; eyes full, shallow. References: Vick's Floral Guide, 1887, p. 164; 1889, p. 93; L. L. Olds's seed catalogue, 1891, p. 4.

Note.—It is not quite clear to the writer what Vick means by "chance seedling." Moreover, the writer has not yet learned where Olds gets his authority for the statement, "It is the first and only instance where the 'Ohio' has been reproduced from seed."

Ohio, Jr., Early. See EARLY OHIO, JR.

Ohio, Late. See LATE OHIO.

Ohio, New White. Synonym of WHITE OHIO.

Ohio Wonder. (Group 9, section 1.) Origin not known.

Description.—Season medium to late. Vines strong and healthy. Tubers oval to nearly round; in cross section, oval to somewhat flattened; eyes few and nearly even with the surface; skin pure white, slightly netted. Reference: Ford Seed Co.'s catalogue, 1907, p. 50.

Old Early Rose. (Group 4, section 3.) Origin unknown.

Description.—Season medium. Vines large, vigorous; flowers purple. Tubers round-oblong to broadly round-flattened, with rather blunt ends; eyes large, rather deep, and occasionally protuberant, deep pinkish color; skin flesh to pink. Base of sprouts pink to purple; internodes creamy white to pink; tips pink to purple.

Old Jersey Peachblow. Synonym of JERSEY PEACHBLOW.

Olds's Golden Russet. See GOLDEN RUSSET, OLDS'S.

Orange, Wall's. Originated by Lyman Wall, of Monroe County, N. Y., in 1879. Grown from a seed ball of a local variety. Introduced by I. F. Tillinghast in 1882.

Description.—Matures late. Vines strong and healthy; flowers purple. Tubers oblong-flattened; skin orange with shading and splashes of pinkish purple; flesh white. References: Cultivator and Country Gentleman, vol. 47, 1882, p. 231; B. K. Bliss & Sons' potato catalogue, 1883, p. 10; Frank Ford's seed catalogue, 1883, p. 14; H. M. Smith's catalogue, 1883, p. 4; Aaron Low's catalogue, 1884, p. 21.

Page's Extra-Early Surprise. Synonym of EARLY SURPRISE.

Page's Peerless. See PEERLESS, PAGE'S.

Pat Murphy. Originated by H. Ernest Hopkins, Conneautville, Pa., in 1901; claimed to be a seedling of Livingston. Introduced by the L. L. Olds Seed Co. in 1911. Reference: Personal letter from H. E. Hopkins to the writer.

Description.—Vines strong, foliage dark green; profuse, beautiful, dark purple flowers; produces seed balls freely. Tubers smooth; eyes fairly shallow; skin nearly white, suffused and flushed with shades of pink and red, always with deep color in the eye cavity. Reference: L. L. Olds's seed catalogue, 1911.

Pat's Choice. Originated by Frank N. Kirkpatrick, of Minnesota; claimed to be a seedling of Seneca Beauty. Introduced by L. L. Olds in 1900.

Description.—Resembles its parent, but is about two weeks earlier. Tubers medium to large, long; eyes very shallow, pink; skin pink of a little lighter shade, covered with a thick netting. References: L. L. Olds's seed catalogue, 1900, p. 2; Rural New Yorker, vol. 61, 1902, p. 128.

Peachblow. Synonym of JERSEY PEACHBLOW and WESTERN RED.

Peachblow, Early. See EARLY PEACHBLOW.

Peachblow, Extra-Early. (Group 11.) Claimed to be a seedling of Early Vermont crossed with White Peachblow. Introduced by B. K. Bliss & Sons in 1881.

Description.—Season early. Tubers compact in hill, flattish round, uniform in size; eyes blotched and shaded with pink; skin russet white; flesh pure white, firm, fine grained. References: B. K. Bliss & Sons' potato catalogue, 1881, p. 6; 1882, p. 9.

Peachblow, Hall's Early. See EARLY PEACHBLOW, HALL'S.

Peachblow, Improved. (Group 11.) Originated by A. Rand, Shelburne, Vt., in 1873; claimed to be a seedling of Jersey Peachblow crossed with Excelsior. Introduced by B. K. Bliss & Sons in 1877.

Description.—Season late; ripens somewhat earlier than Peachblow. Vines and leaves resemble those of Excelsior, while tubers resemble those of Peachblow. References: B. K. Bliss & Sons' potato catalogue, 1877, p. 8; 1878, p. 17; Peter Henderson & Co.'s seed catalogue, 1877, p. 67.

Peachblow, Jersey. See JERSEY PEACHBLOW.

Peachblow, Nichol's New Improved. (Group 11.) Originated by William F. Nichol. Introduced by the St. Louis Seed Co. in 1905.

Description.—Tubers large, white, smooth; eyes handsome, shallow, pink. Reference: St. Louis Seed Co.'s catalogue, 1905, p. 51.

Peachblow, Nott's. (Group 11.) Originated by Richard Nott, Burlington, Vt.

Description.—Matures early. Vines of rather dwarf growth. Tubers roundish, smooth; eyes pink; flesh whitish. Reference: Rural New Yorker, vol. 56, 1897, p. 7.

Peachblow, Old Jersey. Synonym of JERSEY PEACHBLOW.

Peachblow, Perfect. See PERFECT PEACHBLOW.

Peachblow, Thorburn's New White. (Group 11.) Claimed to be a seedling of the Excelsior. Introduced by J. M. Thorburn & Co.

Description.—Vines make a heavy, luxuriant growth; flowers large, purple. Skin and flesh of tubers extremely white. Reference: J. M. Thorburn & Co.'s seed catalogue, 1897, p. 10.

Peachblow, White. See WHITE PEACHBLOW.

Pearl. Synonym, *Peerless*. (Group 10, section 1.) Origin unknown, except by inference; supposed to be a sport of Blue Victor.

Description.—Midseason variety. Vines strong, healthy, medium to large; stems medium dark green, rather stocky, upright in the early part of the season, but gradually assuming a decumbent position as plant approaches maturity; lateral branches in normal plants are more or less erect; leaves large, rather flat, somewhat rugose and medium dark green; flowers white. Tubers medium to large size, round-flattened to heart-shape flattened, usually heavily shouldered and broader at stem end; eyes rather shallow, sometimes protuberant when overdeveloped; in normal condition the bud-eye cluster is shallow; when freshly dug there is a distinct pinkish or light purple tinge around the eyes, particularly at the seed end, but after exposure to light or after prolonged storage this color

is not so noticeable: skin a dull white or light russet or brownish white, usually roughened or crackled; flesh solid and quite heavy. Sprouts have base, leaf scales, and tips slightly suffused with light lilac.

Note.—Fitch says, "The Pearl originated and still comes by bud variation from the Blue Victor." Reference: Colorado Agricultural Experiment Station, bulletin 176, 1910, p. 3. In harvesting the 1914 crop of Pearls at Caribou, Me., the writer was fortunate enough to observe a single example of a reversion to the Blue Victor type. In the progeny of one plant grown from a single seed piece, six of the seven tubers were typical Pearls, while the seventh was a perfect Blue Victor. In some sections the Pearl is known under the name of Peerless, but such a designation is considered inadvisable, since the true Peerless potato is an entirely different variety.

Pearl, Early. See EARLY PEARL.

Pearl of Cannon Valley. Originated in 1897 from seed balls procured from Germany by the Farmer Seed Co. Introduced by the same firm in 1903.

Description.—Very robust grower. Tubers oblong, nearly oval; eyes few, even with the surface; skin a light cream color, russety. Reference: Farmer Seed Co.'s catalogue, 1903, p. 28.

Pearl of Savoy. Originated by Joseph Breck & Sons, of Massachusetts; claimed to be a seedling of Clark's No. 1 crossed with Extra-Early Vermont. Introduced by Joseph Breck & Sons in 1884.

Description.—Fifteen to twenty days earlier than Early Rose. Vines hardy and vigorous. Tubers oblong, fair, large; flesh pearl white. References: Joseph Breck & Sons' seed catalogue, 1884, pp. 8 and 12; 1886, pp. ix, 29, and 33; Cultivator and Country Gentleman, vol. 50, 1885, p. 247.

Peerless. Synonym of PEARL. (See note under PEARL.)

Peerless. Synonym, *Bresee's No. 6.* (Group 9, section 1.) Originated by Albert Bresee, of Hubbardton, Vt., in 1862; claimed to be a seedling of Garnet Chili and from the same seed ball as Early Rose. Introduced by B. K. Bliss & Sons in 1870.

Description.—A main-crop variety. Vines erect and strong with large pale-green leaves. Tubers large and handsome, roundish, oblong or oval, a little flattened; eyes large, yet not so much depressed as to impair the general smoothness of the tubers; skin dull white, occasionally coated with russet; eyes shallow; flesh white. References: B. K. Bliss & Sons' seed catalogue, 1870, p. 80; 1871, p. 80; B. K. Bliss & Sons' circular of potato premiums, 1876, p. 8; H. P. Closson's catalogue, 1870; American Agriculturist, vol. 31, 1872, p. 130; American Journal of Horticulture, vol. 8, 1870, pp. 85-86.

Peerless, Page's. Originated by Page & Son, of Stanfield, Oreg.

Description.—Season very early. It is claimed that when the tubers reach their full growth the vines die down and no secondary growth occurs. Tubers rather stubby and very smooth; skin white. Reference: Fruit Trade Journal and Produce Record, December 25, 1908, p. 28.

People's. (Group 10, section 1.) Originated in Illinois in 1885 (Frank Ford says, "A new variety originated in Minnesota"); claimed to be a seedling from a cross between Minnesota Seedling and Pearl of Savoy. (The Minnesota is a seedling of Burbank crossed with Early Ohio.) Introduced in 1890.

Description.—The originator says, "Vines heavy and strong. Tubers a beautiful oval, oblong to round, large to very large; eyes few, shallow; skin russet white or tan, sometimes splashed with pink." (Ford says, "creamy white, very much russeted"); flesh white. References: Frank Ford & Sons' seed catalogue, 1890, p. 28; W. H. Maule's seed catalogue, 1891, p. 62.

Note.—It is impossible to determine whether or not this variety is identical with the People's now grown in the West. The shape of the tubers does not

coincide, but the color of the skin is identical. Fitch claims that the People's is a sport of the Blue Victor and that it occasionally produces tubers with colored eyes which when propagated produce the Blue Victor. Reference: Colorado Agricultural Experiment Station, bulletin 176, 1910, p. 3.

Perfect Peachblow. (Group 11.) Originated by W. H. Rand, Shelburne, Vt.; claimed to be a seedling of the old White Peachblow.

Description.—Tubers round oblong; eyes bright pink, very few and small; skin russety, sometimes splotched with purple, especially near the stems; flesh pure white. Reference: Rural New Yorker, vol. 45, 1886, p. 33.

Note.—This is apparently not the Perfect or Improved Peachblow grown in the Carbondale, Colo., district.

Petoskey, Early. See EARLY PETOSKEY.

Petoskey, Late. See LATE PETOSKEY.

Philadelphia. Synonym of MERCEUR.

Pingree. Originated by Martin Bovee, Northville, Mich., in 1894; claimed to be a seedling of Green Mountain.

Description.—Season early. Vines medium in size, but strong and spreading. Tubers very smooth and regular; eyes few, shallow; skin white with a thick netting. References: Northrup, King & Co.'s seed catalogue, 1898, back cover page; L. L. Olds's seed catalogue, 1899, p. 2.

Pinkeye, Early. Synonym of DYKEMAN.

Pinkeye, Round. Synonym of DYKEMAN.

Polaris. Originated by H. F. Smith, of Vermont, in 1884; claimed to be a sport of Early Rose. Pharo says, "A seedling of Early Rose crossed with Jackson White." Introduced by H. F. Smith in 1886.

Description.—Season very early. Tubers rather oblong, a little flattened; eyes few and shallow; skin white. References: J. J. H. Gregory's seed catalogue, 1889, p. 5; L. L. Olds's seed catalogue, 1897, p. 5 (see JOSEPH); Pharo's Chart.

Potentate. (Group 1.) Originated by Thomas Craine, Fort Atkinson, Wis. (Maule says it originated in Iowa).

Description.—Season early. Tubers round to oblong, considerably flattened; eyes in clusters and prominent except at seed end, where they are somewhat sunken; skin white, slightly netted. References: Frank Ford & Son's seed catalogue, 1885, p. 13; W. H. Maule's seed catalogue, 1889, p. 12.

Pride. (Group 8, section 1.) Origin not known.

Description.—Tubers variable in shape; eyes medium; skin buff. Reference: Rural New Yorker, vol. 55, 1896, p. 231.

Pride, Clark's. Synonym, *Ensign Bagley*. Originated by Mr. Clark in Aroostook Valley, Me.; parentage not known.

Description.—Season early. Gregory says, "This variety should not be confounded with Clark's No. 1, which we introduced several years ago. Vines stout and healthy, not subject to blight. Tubers very symmetrical; eyes shallow; skin white." References: J. J. H. Gregory's seed catalogue, 1905, p. 3; G. W. P. Jerrard Co.'s catalogue, 1906, p. 11.

Pride of Multnomah. (Group 7.) Originated in Multnomah County, near Portland, Ore. Introduced by the Portland Seed Co. in 1909.

Description.—Season late. A vigorous-growing, heavy-yielding, main-crop variety. Tubers elongated; eyes shallow; skin white. Claimed to possess drought and disease resistant qualities. References: Portland Seed Co.'s catalogue, 1909, p. 56; Portland Seed Co.'s seed annual, 1911, p. 48.

Pride of the South. Synonyms, *White Bliss*, *White Triumph*. (Group 2.) Origin not known; it is not improbable that it is a sport of *Triumph*.

Description.—Season early. Vine characteristics similar to those of *White Triumph* and *Triumph*. Tubers tend to become slightly longer than those of *White Triumph*; eyes as a rule deeply suffused with carmine; skin creamy white, more or less sprinkled with splashes of pink or carmine. This variety is usually listed as identical with *White Triumph* or *White Bliss*.

Prize Early Dakota. (Group 5.) Origin not given.

Description.—Matures early. Vines stiffly erect; leaves heavy, broad, flat, deep green. Tubers nearly globular; eyes shallow; skin splashed with rosy crimson, especially around the eyes. Reference: Northern Seed Co.'s catalogue, 1912, p. 10.

Prolific, Bresee's. Synonym, *Bresee's No. 2*. Originated by Albert Bresee, Hubbardton, Vt., in 1861; claimed to be a seedling of Garnet Chili raised from the same seed ball as *Early Rose*. Introduced by B. K. Bliss & Sons in 1869.

Description.—Season medium; matures about three weeks later than *Early Rose*. Vines of medium height, quite bushy, somewhat spreading; leaves large. Yield very large. Tubers large, regular, very smooth, slightly oblong, somewhat flattened; eyes but little depressed and slightly pinkish; skin dull white, inclined to be russeted; flesh white; cooks quickly, is very mealy, and of excellent quality. References: *The Horticulturist*, vol. 24, 1869, p. 50; John W. Adam's catalogue, 1869, p. 11; C. E. Hovey & Co.'s catalogue, 1869, p. 137; *American Agriculturist*, vol. 28, 1869, p. 30; *American Journal of Horticulture*, vol. 5, 1869, p. 32; B. K. Bliss & Sons' potato catalogue, 1871, p. 80 (illus.).

Prosperity. (Group 9, section 1.) Originated by Elijah Beardsley, of New London, Ohio, in 1900; claimed to be a seedling of *Early Sunrise*. Reference: Personal letter from Samuel Gettle to the writer, January 17, 1912.

Description.—Tubers generally oblong to obovoid, broad, flattened; eyes few, slightly depressed; skin dull buff to dull yellow; sprouts violet tipped.

Prosperity, Early. See *EARLY PROSPERITY*.

Puritan, Early. See *EARLY PURITAN*.

Puritan, Late. See *LATE PURITAN*.

Queen of the West. Synonym of *MAGGIE MURPHY*.

Quick Crop. (Group 6.) Originated in Vermont.

Description.—Season early. Vines vigorous, healthy, dark green. Tubers oblong, smooth, full; resemble *Beauty of Hebron* in color, being a little more clouded. Vick says, "Tubers oval to long, skin light rose color." References: Robert Evans Seed Co.'s catalogue, 1900, p. 21; Vick's *Garden and Floral Guide*, 1900, p. 107.

Quick Lunch. (Group 2.) Originated by Gideon Safford, North Bennington, Vt., in 1890; claimed to be a seedling of the *Peachblow*. Introduced by W. A. Burpee in 1905.

Description.—Season very early; ten days to two weeks earlier than early *Rose*. Tubers nearly globular in form; eyes shallow, with a pinkish cast around each eye; skin brownish white, flaked with rosy crimson. Reference: W. A. Burpee's *Farm Annual*, 1905, pp. 22-23.

Note.—This variety, so far as can be observed, is identical with *Noroton Beauty*. The originator and the introducer, however, stoutly maintain that the two varieties had a separate origin.

Ratkin's Red River Special. See *RED RIVER SPECIAL*, *RATEKIN'S*.

Red Bliss. Synonym of *TRIUMPH*.

Red McClure. Originated at Carbondale, Colo.; claimed to be a sport from the Improved Peachblow.

Description.—A medium-late, strong-growing variety. Tubers large, round; skin deep red; flesh white. Reference: Carpenter Seed Co.'s catalogue, 1910, p. 17.

Note.—Claimed to be identical with the Improved or Perfect Peachblow.

Red Mercer. Synonym of LONG RED.

Red River Special, Ratekin's. Originated on Ratekin's seed farm in the Red River Valley in 1907; claimed to be a seedling of the Early Ohio. Introduced by Ratekin in 1912.

Description.—Season very early. Vines strong, with exceptionally deep-green foliage. Tubers similar to those of the Ohio in shape; eyes small; skin white; flesh pure white. Reference: Ratekin's Seed Book, 1912, p. 52 and inside of back cover.

Note.—The tubers received by the Department of Agriculture from J. W. Ratekin, April 26, 1912, were identical with Early Ohio, both in shape and color. His claim that they were white skinned was not sustained. The writer has no hesitancy in saying that the tubers received as Ratekin's Red River Special were straight Early Ohios.

Red River White Ohio. Synonym of WHITE OHIO.

Red Rose, Extra-Early. See EXTRA-EARLY RED ROSE.

Red Six Weeks. Synonym of TRIUMPH.

Reliance, Alexander's. Originated by O. H. Alexander, Charlotte, Vt., in 1885; claimed to be a seedling of Old Excelsior. Introduced by W. H. Maule in 1904.

Description.—Vines of medium height; leaves large. Tubers roundish and slightly flattened; eyes small, somewhat pinkish; skin white; flesh white. Reference: The Maule Seed Book, 1904, p. 145.

Rhind's Hybrid. (Group 9, section 1.) Originated by Duncan Rhind; claimed to be a seedling of Rural New Yorker No. 2.

Note.—This variety seems to be identical with Rural New Yorker No. 2, both in habit of growth and in tuber characters.

Rochester Rose. (Group 4, section 1.) Claimed to be a seedling of the Early Rose. Introduced by Peter Henderson in 1892.

Description.—An improvement in every respect over the Early Rose; season equally early; averages larger in size and is a better yielder. Reference: Peter Henderson & Co.'s seed catalogue, 1892, p. 7.

Rose, Campbell's Late. See LATE ROSE, CAMPBELL'S.

Rose, Early. See EARLY ROSE.

Rose, Extra-Early Red. See EXTRA-EARLY RED ROSE.

Rose, Extra-Early White. See WHITE ROSE, EXTRA-EARLY.

Rose, Honeoye. See HONEOYE ROSE.

Rose, Houlton. See HOULTON ROSE.

Rose, Improved Early. Synonym of EARLY ROSE.

Rose, Late. See LATE ROSE.

Rose, Maine. Synonym of EARLY MAINE.

Rose, New Scotch. See NEW SCOTCH ROSE.

Rose, Old Early. See OLD EARLY ROSE.

Rose No. 4. Synonym of SPAULDING NO. 4.

Roser, Early. See EARLY ROSER.

Rough Purple Chili. In May, 1851, C. E. Goodrich, of Utica, N. Y., received eight South American potatoes from a friend in Panama. The Rough Purple Chili was regarded as the only one of promise.

Description.—Ripens late in the season. Very hardy. Vines few, stout, erect, almost black; veins and leaves very dark green; flowers dark lilac, always followed by a few balls. Tubers deep purple, knotty, and hollow when grown on rich soils; eyes longish, deep; skin rough; flesh white and of excellent table quality. References: Country Gentleman, vol. 9, 1857, p. 330; vol. 22, 1863, p. 155.

Note.—The Rough Purple Chili is the parent of the Garnet Chili and the grandparent of the Early Rose.

Round Pinkeye. Synonym of DYKEMAN.

Rubicund. Originated by C. G. Pringle, Charlotte, Vt., in 1875; claimed to be a seedling of Early Rose crossed with Peachblow. Introduced by B. K. Bliss & Sons in 1883.

Description.—Ripens medium late. Vines vigorous and healthy. Tubers longish oval, pointed, and somewhat depressed; skin a peculiar reddish bronze with bright purplish lines near the eyes. Reference: B. K. Bliss & Sons' potato catalogue, 1883, p. 6; American Garden, vol. 4, 1883, p. 83.

Ruby. Originated by C. G. Pringle in 1871; claimed to be a seedling of Early Rose crossed with Peachblow. Introduced by B. K. Bliss & Sons in 1875.

Description.—Season early; matures with Early Rose. Vines short and stout with thick, broad, dark-green foliage. Tubers oblong; slightly flattened, resembling those of the Early Rose; eyes carmine, but slightly sunken; skin red, deepened by the carmine which shows in the blotches of the white Peachblow; flesh white, fine grained, and of excellent flavor. References: B. K. Bliss & Sons' circular of potato premiums, 1876; B. K. Bliss & Sons' potato catalogue, 1877, p. 9.

Rural Blush. Synonym, *New Blush*. Originated by E. S. Benham, Attica, N. Y.; parentage not given. Introduced by the Rural New Yorker in 1882. Received by the Rural New Yorker from E. S. Benham in 1880.

Description.—Season intermediate. Vines bear small leaves; stems are noted for their branching habit and slenderness; seldom bloom profusely. Tubers medium size and singularly uniform, never growing very large and seldom being very small; skin white except at the seed end, where it assumes a rosy color, from which the name Blush was derived. References: Rural New Yorker, vol. 41, 1882, pp. 569-570 and p. 779 (fig. 432); vol. 42, 1883, p. 596. Frank Ford & Son describe it as follows: "Tubers nearly round, a little elongated, considerably flattened; eyes few; skin light flesh color, much russeted, with decided rose tint about eyes and seed end." Reference: Frank Ford & Son's seed catalogue, 1884, p. 15.

Note.—As grown in western New York and northern Maine the color of the tubers varies from flesh to pink. In certain sections of New Jersey the skin is said to be almost devoid of color.

Rural New Yorker No. 1. See CARMAN No. 1.

Rural New Yorker No. 2. (Group 9, section 1.) Originated by E. S. Carman; claimed to be a seedling of seedlings raised through several generations. Introduced to Rural New Yorker subscribers in a very limited way in 1888. Offered by J. M. Thorburn & Co. in 1889.

Description.—Season medium late. Vines thrifty and strong. Tubers oblong, inclined to round or round-oval, rather flattened; eyes few, shallow; skin pure white, netted; flesh white. References: Rural New Yorker, vol. 45, 1886, pp. 839-840; J. M. Thorburn & Co.'s seed catalogue, 1889, p. 8; Frank Ford & Son's seed catalogue, 1890, p. 28.

Rural Russet. Synonym of LATE PETOSKEY.

Russet Burbank. Synonym, *California Russet*.

Note.—Similar in every way to Burbank's Seedling, except that the skin is very deeply netted and russeted.

Russet, California. See CALIFORNIA RUSSET.

Russet, Cambridge. See CAMBRIDGE RUSSET.

Russet, Dibble's. (Group 9, section 2.) Origin not known. Introduced by E. F. Dibble in 1912.

Description.—Vines vigorous and healthy. Tubers round; skin white, covered with russet. Reference: E. F. Dibble's farm-seed catalogue, 1912, p. 4.

Russet, Early. See EARLY RUSSET.

Russet, Henderson's Early. Synonym of EARLY RUSSET.

Rustproof. (Group 8, section 2.) Originated by N. P. Hulett, of Pawlet, Vt., about 1900.

Description.—Strong-growing variety of the Green Mountain type, but somewhat later; stems light green; foliage heavy; leaves large and medium green; flowers profusely, but rarely sets seed balls. Tubers large, oblong, broad, and flattened, very similar to Green Mountain, but with smoother skin; eyes not abundant, shallow; skin creamy white.

St. Patrick. Originated by Henry S. Goodale, Sky Farm, Mass.; claimed to be a direct descendant of Garnet Chili and Early Rose. Introduced by Peter Henderson & Co. in 1879.

Description.—Season medium early. Vigorous, compact habit of growth. Tubers oblong rather than round; eyes few and shallow; skin white and smooth; flesh white. References: Peter Henderson & Co.'s seed catalogue, 1882, p. 41; Frank Ford's seed catalogue, 1882, p. 14; D. M. Ferry & Co.'s catalogue, 1884.

Salzer's Scabproof. See SCABPROOF, SALZER'S.

Scabproof, Salzer's. (Group 7, section 2.) Origin not given. Evidently introduced by Salzer under this name in 1904. Reference: John A. Salzer Seed Co.'s catalogue, 1904, p. 124.

Description.—Season medium to medium late. Vines of medium size and vigor; stems dark green; leaves medium size, rather rough, somewhat rugose, dark green; flowers white. Tubers elongate or cylindrical, usually somewhat flattened; eyes medium to numerous; skin usually deeply russeted and rough. Sprouts usually pink, with faint tinge of lilac at base and tips. Very similar to Cambridge Russet.

Sebec, Early. See EARLY SEBEC.

Seneca Beauty. (Group 4, section 3.) Originated in northern Ohio; claimed to be a seedling. Introduced by A. W. Livingston in 1888.

Description.—Season medium late. Vines rank and healthy, blossoming profusely. Tubers large to very large, long, and very smooth; eyes few, shallow; skin distinct pink. References: A. W. Livingston's seed catalogue, 1890, p. 10; 1891, p. 11; 1895, p. 65.

Shaw, Early. See EARLY SHAW.

Silver Skin. Originated by A. Rand, Shelburne, Vt., in 1875; claimed to be a seedling of Early Rose crossed with White Peachblow. Introduced by B. K. Bliss & Sons in 1880.

Description.—Resembles the Peerless in many respects, but is earlier and of better quality. Vines of medium height, quite stocky, and of compact growth. Tubers medium to large; oval to oblong; skin silvery white, smooth, sometimes slightly russeted; flesh white. Reference: B. K. Bliss & Sons' potato catalogue, 1881, p. 13.

Sir Walter Raleigh. (Group 9, section 1.) Originated by E. S. Carman; claimed to be a seedling of the Rural New Yorker No. 2. Introduced by Peter Henderson & Co. in 1897.

Description.—Vines similar in habit and color of flowers to those of the Rural New Yorker No. 2, but color of stems not as pronounced. Color of flesh and skin of the tubers is the same, but quality is better. References: Rural New Yorker, vol. 51, 1892, pp. 202 and 675; vol. 55, 1896, p. 754; Peter Henderson & Co.'s seed catalogue, 1897, p. 12.

Six Weeks. Synonym of EARLY SIX WEEKS.

Six Weeks, Early. See EARLY SIX WEEKS.

Six Weeks Market, Early. See EARLY SIX WEEKS MARKET.

Smith's Blightless Wonder. See BLIGHTLESS WONDER, SMITH'S.

Snow. (Group 8, section 1.) Originated by W. E. Johnson, Richmond, Me. Introduced by the Johnson Seed Potato Co.

Description.—Vines strong and healthy; stems light green; foliage heavy; leaves rather large and medium green; it flowers freely, but ordinarily sets few seed balls. Tubers large, oblong, and broad-flattened, generally with blunt ends, base usually more or less notched; eyes medium in size and number; skin creamy white, netted. Very similar to Green Mountain.

Snowflake. Originated by C. G. Pringle, Charlotte, Vt., in 1869; claimed to be a seedling (Early Rose crossed with White Peachblow) crossed with Excelsior. Introduced by B. K. Bliss & Sons in 1873.

Description.—Season second early. Tubers elongate-oval, compressed, exceedingly symmetrical; eyes few, shallow except at seed end; skin white with a russet tinge and somewhat roughish and tessellated; flesh snowy white, fine grained, and of superior quality. References: B. K. Bliss & Sons' potato catalogue, 1874, p. 3; 1877, pp. 11 and 13; 1878, pp. 20–22; Cultivator and Country Gentleman, vol. 39, 1874, p. 243.

Snowflake, Late. See LATE SNOWFLAKE.

Somers' Extra-Early. See EXTRA EARLY, SOMERS'.

Spanish. Synonym of LONG RED.

Spaulding. Origin not given. Introduced by Frank Ford & Son in 1885.

Description.—Season medium. Tubers oval, considerably flattened, good size; eyes few, shallow; skin white, finely netted. Reference: Frank Ford & Son's seed catalogue, 1885, p. 14.

Spaulding No. 4. Synonym, *Rose No. 4.* (Group 4, section 2.) Origin not given.

Description.—Season medium early. Tubers inclined to be oblong and thicker than Early Rose; skin a trifle lighter pink. Reference: Ross Bros.' catalogue, 1904, p. 24.

Standard, Dreer's. Origin not known. Introduced by Henry A. Dreer in 1890.

Description.—Season early. Vines healthy, medium size, with deep green foliage. Tubers oval, similar in form to the old Early Vermont; skin white; flesh white. Reference: Henry A. Dreer's Garden Calendar, 1890, p. v.

Standard, Dreer's Early. See EARLY STANDARD, DREER'S.

Star of the East. (Group 6.) Originated by W. E. Johnson, Richmond, Me., in 1900; claimed to be a seedling of Johnson's Dewey crossed with Johnson's No. 1. Introduced by the Johnson Seed Potato Co. in 1905.

Description.—Vines stout. Tubers oblong and very large. Reference: Johnson Seed Potato Co.'s catalogue, 1905, p. 19.

Note.—The tuber represented in the cut in the Johnson Seed Potato Co.'s catalogue is elongated and pointed at the seed end with numerous, apparently deep eyes; altogether the shape seems very undesirable.

State of Maine. (Group 8.) Claimed to be a seedling of Early Vermont crossed with Peerless. Introduced by D. Landreth & Sons in 1884.

Description.—Season medium early. Vines vigorous, erect; leaves glossy, flowers white. Tubers cylindrical, slightly elongated; eyes similar to those of the Early Rose; skin buff, sometimes russeted; flesh white. References: Rural New Yorker, vol. 42, 1883, p. 718 (fig. 672, p. 719); D. Landreth & Sons' catalogue, 1884, p. 55; 1892, p. 40; Henry A. Dreer's Garden Calendar, 1889, p. 32.

Stray Beauty. Synonym of TRIUMPH.

Sunlight. Synonym, *Early Sunlight*. Claimed to have been grown from seed produced by crossing two early white-skinned sorts.

Description.—Season extra early. Vines robust. Tubers of handsome shape, inclined to oblong, broad, but not very thick; eyes shallow; skin white; flesh white. References: Salzer Seed Co.'s catalogue, 1900, pp. 109–110; William Rennie Co.'s seed catalogue, 1905, p. 25.

Sunlight, Early. Synonym of SUNLIGHT.

Superior, Brownell's. Originated by E. S. Brownell, Essex Junction, Vt., in 1873; claimed to have been grown from a seed ball of Brownell's Beauty crossed with White Peachblow.

Description.—Season second early or medium late. Vines strong and healthy. Tubers medium to large, elongate-oval or cylindrical; eyes few and small; skin a peculiar dark copper color, fine and smooth. References: B. K. Bliss & Sons' potato catalogue, 1877, p. 16; Peter Henderson & Co.'s seed catalogue, 1875, p. 67. "Season medium. Vines small. Tubers oblong in shape; eyes few and small; skin red or deep flesh." Reference: Cultivator and Country Gentleman, vol. 40, 1875, p. 35.

Superior, Burpee's. Originated by E. L. Coy, Hebron, N. Y., in 1884; claimed to be a seedling of White Star. Introduced by W. A. Burpee in 1889.

Description.—Season medium late. Vines strong, foliage heavy. Somewhat resembles parent in shape, but is more compact in form. Tubers of good size and shape, growing compactly in hill; eyes shallow; skin and flesh very white. References: W. A. Burpee's Farm Annual, 1889, p. 12; Rural New Yorker, vol. 43, 1889, p. 103.

Surprise, Early. See EARLY SURPRISE.

Surprise, Page's Extra Early. Synonym of EARLY SURPRISE.

Telephone, Early. See EARLY TELEPHONE.

Thorburn. (Group 4, section 1.) Originated by E. L. Coy, Hebron, N. Y.; claimed to be a seedling of Beauty of Hebron. Introduced by J. M. Thorburn & Co. in 1886.

Description.—Season medium, about as early as Early Rose. Tubers cylindrical-oblong, sometimes a little flattened; eyes medium in number and prominence; skin white; flesh white. References: Rural New Yorker, vol. 44, 1885, pp. 804–805 (fig. 501); J. M. Thorburn & Co.'s seed catalogue; 1886, p. 32.

Note.—The variety now grown as Thorburn has flesh or light-pink skin.

Thorburn's New White Peachblow. See PEACHBLOW, THORBURN'S NEW WHITE.

Thoroughbred, Early. See EARLY THOROUGHbred.

Triumph. Synonyms, *Bliss's Triumph*, *Red Bliss*, *Stray Beauty*, *Red Six Weeks*, *Early Hunt*. (Group 2.) Originated in Connecticut; claimed to be a seedling of Peerless crossed with a seedling of Early Rose. Introduced by B. K. Bliss & Sons in 1878.

Description.—Season early, matures about 10 days earlier than Early Rose and is more productive. Vines erect; foliage dark green. Tubers medium size, round, uniform in shape; eyes slightly depressed; skin light red; flesh fine

grained. References: B. K. Bliss & Sons' potato catalogue, 1878, p. 13; 1880, p. 17; J. J. H. Gregory's seed catalogue, 1879, p. 55.

Triumph, Early White. Synonym of WHITE TRIUMPH.

Triumph, White. See WHITE TRIUMPH.

Trophy. Originated by O. H. Alexander, Charlotte, Vt., from Pringle's hybridized seed; claimed to be a seedling of Ruby crossed with Excelsior. Introduced by B. K. Bliss & Sons in 1878.

Description.—Matures two weeks later than the Early Rose. Vines stout and vigorous; foliage dark green. Tubers medium size, very regular in form, elongate-oval, somewhat flattened; eyes very few, almost flat upon the surface; skin reddish, slightly russeted; flesh white, fine grained, and of excellent quality. References: Cultivator and Country Gentleman, vol. 43, 1878, p. 215; B. K. Bliss & Sons' potato catalogue, 1878, p. 12; 1880, p. 15.

Twentieth Century. Said to have been originated by a Scotchman named Milne; parentage not given.

Description.—Season intermediate. Vines vigorous, spreading; leaves dark green; no flowers. Tubers often larger at one end than at the other; eyes few, not prominent; skin russet; flesh nearly white. Thought to bear a close resemblance to Diamond. References: Rural New Yorker, vol. 57, 1898, p. 54; Johnson & Stokes's Garden and Farm Manual, 1899, p. 6; The Gardener, March 4, 1905, p. 839.

Uncle Sam. (Group 8, section 1.) Origin not given. Introduced by Peter Henderson & Co.

Description.—Season medium late, ripening with Rural New Yorker No. 2. Tubers oval; eyes shallow; skin russet white. Reference: Peter Henderson & Co.'s catalogue, 1896, p. 12.

Vaughan. Originated by E. L. Coy, Hebron, N. Y., in 1885; claimed to be an inbred seedling of Peerless. Introduced by Vaughan in 1891.

Description.—Ripens with Early Puritan. Vines dead before those of Early Rose. Tubers resemble those of Beauty of Hebron in shape, though somewhat more elongated; skin flesh color; flesh very white. References: Vaughan's seed catalogue, 1891, p. 25; Vaughan's Gardening, illustrated, 1893, p. 27; Cole's Garden Annual, 1892, p. 47.

Vermont Champion. Synonym of CHAMPION.

Vermont Early. Synonym of EXTRA-EARLY VERMONT.

Vermont, Extra-Early. Synonym, *Early Vermont*. (Group 4, section 1.) Originated by George W. Woodhouse, West Rutland, Vt., in 1866; claimed to be a seedling of Jackson White naturally fertilized by Garnet Chili. Introduced by B. K. Bliss & Sons in 1872.

Description.—Seven to ten days earlier than Early Rose when grown side by side. Vines of medium height, somewhat spreading. Tubers oblong to long oval; eyes numerous, some prominent, others slightly depressed; flesh white. References: B. K. Bliss & Sons' potato catalogue, 1873, p. 7; 1878, pp. 24 and 25; B. K. Bliss & Sons' seed catalogue, 1873, p. 138; Washburn & Co.'s Amateur Cultivator's Guide, 1873, pp. 121-122.

Vicktor. Synonym, *Early Vicktor*. (Group 1.) Originated in western New York. Introduced by James Vick & Sons in 1903 as New Extra-Early potato; it was named Vicktor the following season.

Description.—Matures in less time than Early Ohio, Early Rose, Boyce, etc. Vines vigorous and healthy; tubers large, rounded, slightly flattened; skin white and somewhat russeted. References: Vick's Garden and Floral Guide, 1903, p. ii; 1904, p. 7.

Note.—Apparently identical with Irish Cobbler.

Victor, Blue. See BLUE VICTOR.

Victor, New. See NEW VICTOR.

Victor, White. See WHITE VICTOR.

Vigorosa. (Group 6.) Originated by D. C. Hicks, North Clarendon, Vt.; claimed to be an inbred seedling of Garnet Chili. Introduced by L. L. Olds in 1897.

Description.—Vines strong and vigorous. Tubers oblong, cylindrical, somewhat flattened; skin a beautiful flesh color with considerable netting; flesh white. Reference: L. L. Olds's seed catalogue, 1897, p. 2.

Wall's Orange. See ORANGE, WALL'S.

Walters, Early. See EARLY WALTERS.

Weld's Jumbo. Synonym of JUMBO.

Wendell. Synonym, *Early Wendell*. Originated by Herman Wendell, Albany, N. Y., in 1847; claimed to be a seedling of Carter. Introduced by R. H. Pease in 1854.

Description.—Season intermediate. Vines healthy and vigorous. Tubers roundish oblong; skin white. References: Country Gentleman, vol. 4, 1854, p. 295; American Journal of Horticulture, vol. 1, 1867, p. 100.

Wendell, Early. Synonym of WENDELL.

Western Red. Synonym, *Peachblow*. Origin not given.

Description.—Vines stout and upright like those of Garnet Chili, but with dark stems and leaves and lilac flowers. Tubers a shade darker red than those of Garnet Chili; eyes scarcely as deep; flesh yellow and quite liable to disease. References: Country Gentleman, vol. 22, 1863, p. 155; The Cultivator, vol. 4 (third series), 1856, p. 158.

White Albino, Early. See EARLY WHITE ALBINO.

White Beauty. Synonym, *Bruce's White Beauty*. (Group 7, section 1.) Origin not given. Introduced by J. A. Bruce & Co. in 1891.

Description.—Season medium; resembles Beauty of Hebron in shape, but earlier and more productive. Tubers uniform in size; skin and flesh pure white. References: J. A. Bruce & Co.'s catalogue, 1894, p. 21; Vick's Garden and Floral Guide, 1898, p. 30.

Note.—Vick claims to have introduced White Beauty in 1898. Whether Vick's White Beauty was identical with that of J. A. Bruce & Co. is not apparent.

White Beauty, Bruce's. Synonym of WHITE BEAUTY.

White Bliss. Synonym of WHITE TRIUMPH.

White Chenango. See CHENANGO, WHITE.

White Chief. (Group 7, section 1.) Origin not given.

Description.—A new, second-early, vigorous-growing variety; foliage dense. Tubers round, oblong, large; eyes few, shallow; skin smooth, white, with a yellow cast; flesh pure white. Reference: Frank Ford & Son's seed catalogue, 1885, p. 13.

White Early Ohio. Synonym of WHITE OHIO.

White Elephant. Synonym, *Late Beauty of Hebron*. (Group 6.) Originated by E. L. Coy, Hebron, N. Y.; claimed to be a seedling of Garnet Chili crossed with White Peachblow. Introduced by J. M. Thorburn & Co. in 1881.

Description.—Ripens with Late Rose. Vines vigorous and stout. Tubers very large and long; eyes numerous and slightly depressed; skin nearly white with a little pink tint. References: J. M. Thorburn & Co.'s seed catalogue, 1881, p. 30; 1882, p. 32; B. K. Bliss & Sons' potato catalogue, 1881, p. 10; 1882, p. 11; Cultivator and Country Gentleman, vol. 45, 1880, p. 249; Frank Ford's seed catalogue, 1882, p. 14; G. W. P. Jerrard Co.'s catalogue, 1894, p. 22; Buist's Garden Guide, 1895, p. 105; Van Ornam's "Potatoes for Profit," 1896, pp. 81-82.

Note.—There is evidently some confusion regarding the identity of White Elephant and Late Beauty of Hebron. The latter variety is claimed to be a sport of the Early Beauty of Hebron and is said to have been originated by E. L. Coy, the originator of White Elephant.

White Giant. (Group 9, section 1.) Origin not given.

Description.—Season medium late. Tubers somewhat oblong; cross sections oval; eyes even with the surface; skin white, netted. Reference: Ford Seed Co.'s catalogue, 1901, p. 37.

Note.—This variety is similar to, if not identical with, Rural New Yorker No. 2.

White Harvest, Gurney's. (Group 8, section 1.) Origin not known.

Description.—Early, productive, white potato. Reference: Gurney Seed & Nursery Co.'s catalogue, 1912, p. 65.

White Mercer. Synonym, *White Meshannock*. Origin not known.

Description.—Season early. Vines small, resembling those of clouded Meshannock. Tubers long, round, smooth; eyes numerous; skin white; flesh white. Reference: Rural New Yorker, vol. 10, 1859, p. 398.

White Meshannock. Synonym of WHITE MERCER.

White Mountain. Synonym, *New White Mountain*. (Group 8, section 1.) Originated by O. H. Alexander, Charlotte, Vt.; claimed to be a sport of Early Potentate. Introduced by Alexander in 1880.

Description.—A medium-late, vigorous-growing variety. Tubers medium to large; eyes even with the surface or slightly bulged above; skin white, with rich, yellowish, creamy cast, considerably netted; flesh white. References: Cultivator and Country Gentleman, vol. 44, 1879, p. 818; J. A. Everitt's seed catalogue, 1899, pp. 52–53.

White Ohio. Synonyms, *New White Ohio*, *White Early Ohio*, *Red River White Ohio*. (Group 5.) Originated by James Vick & Sons in 1892; claimed to be a sport of Early Ohio. Vaughan says, "A western grower found, three years ago (1898), a plant producing pure white potatoes identical with Early Ohio in every point except in color."

Description.—Identical with Early Ohio in every point except color of skin; eyes more or less shaded with pink. References: Vick's Floral Guide, 1896, p. 31; Vaughan's seed catalogue, 1900, p. 39.

Note.—Both sources of origin may be correct, as the Early Ohio has on several occasions been observed by the writer to produce white tubers.

White Peachblow. (Group 11.) Claimed to have been produced from the pit (seed ball) of a Peachblow, by some one at Saratoga, N. Y.

Description.—A little earlier in maturity than the Peachblow. Plants stocky and vigorous, resembling the parent. Tubers about the same size as those of Peachblow; skin clear white except at eyes, which are peach-blossom pink. References: Country Gentleman, vol. 26, 1865, p. 315; American Journal of Horticulture, vol. 1, 1867, p. 100.

White Peachblow, Thorburn's New. See PEACHBLOW, THORBURN'S NEW WHITE.

White Rose, Extra-Early. (Group 4, section 1.) Originated in Aroostook County, Me.

Description.—Season extra early. Tubers similar in shape to those of the old Early Rose; skin white. Reference: T. W. Wood & Sons' catalogue, 1902, p. 5.

White Star. Originated by E. S. Brownell, Essex Junction, Vt., in 1875; claimed to be a seedling of Excelsior crossed with White Peachblow. Introduced in 1881.

Description.—Season medium early. Vines strong, stocky, vigorous; foliage dark green. Tubers oblong and large; skin white, covered with a minute, russet

netting; flesh white. References: B. K. Bliss & Sons' potato catalogue, 1881, p. 6; 1883, pp. 8-9; D. M. Ferry & Co.'s catalogue, 1882, p. 50.

Note.—A. Rand, of Bristol, Vt., a few years ago claimed that White Star was the Burbank renamed. Present available data do not substantiate this claim.

White Swan. (Group 9, section 1.) Origin not given.

Description.—Tubers cylindrical, medium long, tapering at one end; eyes rather deep; skin buff; flesh nearly white. Reference: Rural New Yorker, vol. 45, 1886, p. 281.

White Triumph. Synonyms, *Early White Triumph*, *Pride of the South*, *White Bliss*, *Junior Pride*. (Group 2.) A white sport of Bliss's Triumph. Introduced by the Iowa Seed Co. in 1904.

Description.—Season early; earlier than Early Ohio. Tubers strongly resemble Bliss's Triumph in shape, while in general appearance they are somewhat similar to the Improved Peachblow; eyes not so deep; skin smoother. References: Iowa Seed Co.'s catalogue, 1904, p. 34; D. Landreth & Sons' catalogue, 1910, p. 74; S. L. Lamberd & Co.'s catalogue, 1908, p. 19.

Note.—The skin of the White Triumph is white with an occasional splash of carmine on some tubers, either around the eyes or on other portions. There seems to be some confusion in the minds of seedsmen as to the identity of this variety with *Pride of the South*, many seedsmen claiming that they are identical. As observed by the writer in 1914, the *Pride of the South* showed more color around the eyes and was a slightly longer tuber, not so distinctly roundish as the White Triumph.

White Triumph, Early. Synonym of WHITE TRIUMPH.

White Victor. Originated by Frank Jensen, Waushara County, Wis.; claimed to be a sport of Blue Victor. Introduced by L. L. Olds in 1905.

Description.—Season medium early. Tubers large to very large; eyes few, shallow, symmetrical; skin creamy white, well netted and russeted; flesh white. References: Rural New Yorker, vol. 44, 1885, p. 10; L. L. Olds's catalogue, 1905, p. 2.

Willard. Synonym, *Willard Seedling*. Originated by C. W. Gleason; claimed to be a seedling of Early Goodrich. Introduced by J. J. H. Gregory in 1869.

Description.—Season medium. Vines larger than those of Early Goodrich. Tubers oblong-roundish; eyes medium deep; skin a rich rose color with numerous dots of dull white and occasional splashes of yellowish white; flesh white. References: J. J. H. Gregory's seed catalogue, 1869, p. 20; 1872, p. 34.

Willard Seedling. Synonym of WILLARD.

Winner, Brownell's. (Seedling No. 2000.) Originated by E. S. Brownell, Essex Junction, Vt., in 1885; claimed to be a seedling of White Star crossed with Peachblow. Introduced by W. A. Burpee in 1890.

Description.—Season medium late. Vines wide spreading, vigorous. Tubers large, long, oval, slightly flattened; eyes few, not deep; skin rosy pink; flesh white. References: W. A. Burpee's Farm Annual, 1890, p. 10; Rural New Yorker, vol. 48, 1889, p. 103.

Wisconsin, Early. See EARLY WISCONSIN.

Wonderful. Origin not known. Introduced by J. J. H. Gregory & Son in 1903.

Description.—Season medium late. Tubers large, well shaped, medium to long; eyes close to the surface; skin rich russet brown. Reference: J. J. H. Gregory & Son's seed catalogue, 1905, p. 26.

World's Wonder. Originated by Paul Frederick, Victor, N. Y., in 1898; claimed to be a seedling of Carman No. 3.

Description.—Season medium late. Vines strong and stocky. Tubers nearly round; skin white. Reference: O. K. Seed Store catalogue, 1910, p. 9.



BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE



No. 177

Contribution from the Bureau of Crop Estimates, L. M. Estabrook, Chief.

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THE PRODUCTION AND CONSUMPTION OF DAIRY PRODUCTS.

By EUGENE MERRITT.

INTRODUCTION.

The changes in the geographic distribution of the population, in the centers of agricultural production, and in the methods of transportation have had marked influence on the localization of the dairy industry. In early days the dairyman supplied demands within a restricted area, but the development of railroads and refrigeration has had considerable effect on the character of the dairy industry and its localization. As a part of the agriculture of our country, dairying has had to compete with other types of farming. Since the products of the dairy may be consumed in the form of milk, butter, or cheese, there is a competition among them as to what form the consumption will take. It is the purpose of this bulletin to call attention to the influence of the various factors mentioned above.

PRODUCTION OF DAIRY PRODUCTS.

THE GENERAL SITUATION.

In the last 40 years great changes have taken place in population, in agriculture, and in the various phases of the dairy industry of the United States. In 1870 the total population of the United States was 38,600,000. By 1900 it had nearly doubled and by 1910 lacked a little of being 92,000,000. The number of dairy cows had increased from 9,000,000 in 1870 to nearly 21,000,000 in 1910. The rate of increase for improved land was even greater than that of the population or the dairy cows; in 1870 there were 190,000,000 acres, and in 1910, 480,000,000. The increase in the total butter production had been even more marked, from 514,000,000 in 1870 to nearly three times that amount, or approximately 1,620,000,000 pounds, in 1910. Cheese production, however, did not even double; the increase was from 163,000,000 to 321,000,000 pounds. There have been marked variations in the rates of increase and the relative importance of the

NOTE.—This bulletin outlines the changes in the geographic distribution of the dairy industry and gives information concerning the consumption of dairy products on farms and in cities. It is of special interest to those engaged in any phase of dairying or in the distribution of dairy products.

TABLE 1.—*Population, improved land, dairy cows, and production of butter and cheese, by geographic divisions for 1870, 1880, 1890, 1900, and 1910.*

Year and geographic division. ¹	Population.	Number of dairy cows.	Improved land.	Production for calendar year preceding date of census.	
				Butter.	Cheese.
1910.					
New England.....	6,552,681	841,698	Acres. 7,254,904	Pounds. 68,699,379	Pounds. 3,676,609
Middle Atlantic.....	19,315,892	2,597,652	29,320,894	165,392,518	118,339,484
East North Central.....	18,250,621	4,829,527	88,947,228	424,127,997	180,423,449
West North Central.....	11,637,921	5,327,606	164,284,862	444,724,204	5,286,968
South Atlantic.....	12,194,895	1,810,754	48,479,733	125,256,293	514,137
East South Central.....	8,409,901	1,628,061	43,946,846	136,791,873	93,971
West South Central.....	8,784,534	2,249,553	58,264,273	134,876,201	441,697
Mountain.....	2,633,517	514,466	15,915,002	34,756,687	2,546,955
Pacific.....	4,192,304	826,115	22,038,008	84,780,111	9,208,931
Total, United States	91,972,266	20,625,432	478,451,750	1,619,415,263	320,532,181
1900.					
New England.....	5,592,017	893,478	8,134,403	92,032,196	6,958,700
Middle Atlantic.....	15,454,678	2,602,788	30,786,211	233,986,350	141,259,571
East North Central.....	15,985,581	3,962,481	86,670,271	403,208,930	120,279,089
West North Central.....	10,347,423	4,527,803	135,643,828	407,632,767	13,667,004
South Atlantic.....	10,443,480	1,383,319	46,100,226	92,883,312	593,308
East South Central.....	7,547,757	1,264,282	40,237,337	97,999,645	181,528
West South Central.....	6,532,290	1,634,954	39,770,530	88,856,542	473,381
Mountain.....	1,674,657	329,604	8,402,576	20,499,029	4,709,314
Pacific.....	2,416,692	536,924	18,753,105	54,653,831	10,222,744
Total, United States	75,994,575	17,135,633	414,498,487	1,491,752,602	298,344,639
1890.					
New England.....	4,700,749	822,001	10,738,930	77,240,024	9,107,032
Middle Atlantic.....	12,706,220	2,529,060	31,599,094	217,793,692	130,131,662
East North Central.....	13,478,305	3,752,237	78,774,647	327,051,265	93,779,808
West North Central.....	8,932,112	4,488,762	105,517,479	323,491,323	16,446,053
South Atlantic.....	8,857,922	1,369,466	41,677,371	80,401,070	415,291
East South Central.....	6,429,154	1,312,074	35,729,170	84,955,855	177,070
West South Central.....	4,740,983	1,517,583	30,559,654	50,347,087	172,597
Mountain.....	1,213,935	218,689	5,460,739	8,709,349	739,976
Pacific.....	1,888,334	502,078	17,559,671	35,456,941	5,779,894
Total, United States	62,947,714	16,511,950	357,616,755	1,205,446,606	256,749,383
1880.					
New England.....	4,010,529	746,656	13,148,466	65,934,782	12,202,042
Middle Atlantic.....	10,496,878	2,444,089	33,237,166	211,073,290	138,700,187
East North Central.....	11,206,668	2,990,852	75,589,373	240,351,236	78,950,611
West North Central.....	6,157,443	2,411,229	61,252,946	143,103,863	7,581,959
South Atlantic.....	7,597,197	1,280,761	36,170,331	48,703,330	640,065
East South Central.....	5,585,151	1,145,403	30,820,882	51,603,349	184,538
West South Central.....	3,334,220	1,002,037	18,985,889	22,605,422	92,385
Mountain.....	653,119	124,844	2,213,300	3,205,759	606,392
Pacific.....	1,114,578	297,249	13,352,689	20,091,040	4,199,671
Total, United States	50,155,783	12,443,120	284,771,042	806,672,071	243,157,850
1870.					
New England.....	3,487,924	642,593	11,997,540	49,662,325	16,316,016
Middle Atlantic.....	8,810,806	2,190,429	29,119,645	176,248,193	104,047,024
East North Central.....	9,124,517	2,247,683	54,899,646	156,138,383	35,889,749
West North Central.....	3,856,594	1,046,324	23,509,863	58,262,042	2,151,998
South Atlantic.....	5,853,610	1,001,094	30,202,991	28,575,306	252,190
East South Central.....	4,404,445	835,351	24,218,478	27,273,321	509,290
West South Central.....	2,029,965	659,083	6,870,297	6,789,083	48,208
Mountain.....	315,385	83,419	576,200	1,348,607	181,035
Pacific.....	675,125	229,356	7,526,439	9,795,423	3,531,872
Total, United States	38,558,371	8,935,332	188,921,099	514,092,683	162,927,382

¹ The geographic divisions are as follows: *New England*: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut; *Middle Atlantic*: New York, New Jersey, and Pennsylvania; *East North Central*: Ohio, Indiana, Illinois, Michigan, and Wisconsin; *West North Central*: Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas; *South Atlantic*: Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, and Florida; *East South Central*: Kentucky, Tennessee, Alabama, and Mississippi; *West South Central*: Arkansas, Louisiana, Oklahoma, and Texas; *Mountain*: Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, and Nevada; *Pacific*: Washington, Oregon, and California.

New England and Middle Atlantic divisions combined contain the North Atlantic geographic division and the Mountain and Pacific divisions, the Western.

various geographic divisions in the production of cheese, but these are more easily comprehended by a study of the percentages in Table 3 than by a study of the figures showing production in pounds, as in Table 1.

CHANGES SINCE 1870.

If 1870 is taken as 100, and figures for other census years are expressed as percentages of the corresponding figures for 1870, the changes in the various geographic divisions for the different items mentioned above can be readily comprehended. For the United States, as a whole, the percentage or "index number" for 1910 for improved land is slightly greater than the index numbers for population and for dairy cows. This condition is true for practically all the census years shown for the United States as a whole; but when geographic divisions are considered individually the increase for those east of the Mississippi has not been as rapid as the increase for those west of that river, due primarily to the undeveloped condition of the West prior to 1870 and to its great development since.

There was less improved land in the New England States in 1910 than there was in 1870, while in the Middle Atlantic States the areas of improved farm land in 1870 and 1910 were approximately the same. The increase in dairy cows in the 40 years was slight in the New England and the Middle Atlantic States, yet the increase in the total population in the New England States was about 90 per cent, and in the Middle Atlantic nearly 120 per cent. When the increase in butter and cheese production in the New England and Middle Atlantic States is compared with the increase in total population, the population shows the more rapid advance. In other words, neither agriculture in general nor the dairy industry has kept up with the increase in population in these two geographic divisions.

When similar comparisons are made for the North Central States east of the Mississippi River, the increase in improved land is not as large as the increase in population, yet the increase in dairy cows and in dairy products has excelled the increase in population.

In the South Atlantic, East South Central, and Pacific States the population has increased faster than the improved land in the 40 years under consideration, and the same is true of the dairy cows, except in the East South Central States; yet increase in butter production was greater in all three of the geographic divisions than that for the population. Other changes can readily be noted in Table 2.

TABLE 2.—*Population, improved land, dairy cows, and production of butter and cheese, by geographic divisions, for 1880, 1890, 1900, and 1910, expressed as percentages of 1870.*

[1870=100 per cent.]

Year and geographic division.	Population.	Dairy cows.	Improved land.	Production for calendar year preceding date of census.	
				Butter.	Cheese.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1910.					
New England.....	187.9	131.0	60.5	138.3	22.5
Middle Atlantic.....	219.2	118.6	100.7	93.8	113.7
East North Central.....	200.0	214.9	162.0	271.6	502.7
West North Central.....	301.8	509.2	698.8	763.3	245.7
South Atlantic.....	208.3	180.9	160.5	438.3	203.9
East South Central.....	190.9	194.9	181.5	501.6	18.5
West South Central.....	432.7	341.3	848.1	1,986.7	916.2
Mountain.....	835.0	616.7	2,762.1	2,577.2	1,406.9
Pacific.....	621.0	360.2	292.8	865.5	260.7
Total, United States.....	238.5	230.8	253.3	315.0	196.7
1900.					
New England.....	160.3	139.0	67.8	185.3	42.6
Middle Atlantic.....	175.4	118.8	105.7	132.8	135.8
East North Central.....	175.2	176.3	157.9	258.2	335.1
West North Central.....	268.3	432.7	577.0	699.7	635.1
South Atlantic.....	178.4	138.2	152.6	325.0	235.3
East South Central.....	171.4	151.3	166.1	359.3	35.6
West South Central.....	321.8	248.1	578.9	1,308.8	982.0
Mountain.....	531.0	395.1	1,458.3	1,520.0	2,601.3
Pacific.....	358.0	234.1	249.2	558.0	289.4
Total, United States.....	197.1	191.8	219.4	290.2	183.1
1890.					
New England.....	134.8	127.9	89.5	155.5	55.8
Middle Atlantic.....	144.2	115.5	108.5	123.6	125.1
East North Central.....	147.7	166.9	143.5	209.5	261.3
West North Central.....	231.6	429.0	448.8	555.2	764.2
South Atlantic.....	151.3	136.8	138.0	281.4	164.7
East South Central.....	146.0	157.1	147.5	311.5	34.8
West South Central.....	233.5	230.3	444.8	741.6	358.0
Mountain.....	384.9	262.2	947.7	645.8	408.7
Pacific.....	279.7	218.9	233.3	362.0	163.6
Total, United States.....	163.3	184.8	189.3	234.5	157.6
1880.					
New England.....	115.0	116.2	109.6	132.8	74.8
Middle Atlantic.....	119.1	111.6	114.1	119.8	133.3
East North Central.....	122.8	133.1	137.7	153.9	220.0
West North Central.....	159.7	230.4	260.5	245.6	352.3
South Atlantic.....	129.8	127.9	119.8	170.4	253.8
East South Central.....	126.8	137.1	127.3	189.2	36.2
West South Central.....	164.2	152.0	276.3	333.0	191.6
Mountain.....	207.1	149.7	384.1	237.7	335.0
Pacific.....	165.1	129.6	177.4	205.1	118.9
Total, United States.....	130.1	139.3	150.7	156.9	149.2

CONDITIONS IN DIFFERENT GEOGRAPHIC DIVISIONS.

The variations in the changes of the various elements connected with dairying have had marked influence upon the relative importance of this industry in the different geographic divisions. In 1870 the New England States had 6.4 per cent of the total improved land of the United States, while in 1910 they had only 1.5 per cent. Similar percentages for population were 9 and 7.1, respectively, and for dairy cows 7.2 and 4.1 per cent, of the totals for the United States. For the Middle Atlantic States the changes in the percentages for population have been but slight, while the per cent for improved land had decreased in 1910 to less than half of what it was in 1870, and the per cent of dairy cows decreased nearly one-half. The most marked changes for the East North Central States

have taken place in the improved land, the percentages (computed on the basis of United States totals) decreasing from 29.1 to 18.6, while the changes for population and dairy cows have been but slight. The changes in the population percentages for New England, Middle Atlantic, and East North Central States have been small, yet there has been a marked change in the relative importance of the agriculture and the dairy industry.

TABLE 3.—*Relative importance of the geographic divisions as to population, dairy cows, improved land, butter, and cheese, expressed as percentages of total United States, 1870-1910.*

[In each year shown below, total for United States=100 per cent.]

Year and geographic division.	Popula- tion.	Number of dairy cows.	Area of improved land.	For calendar year pre- ceding date of census.	
				Butter pro- duction.	Cheese pro- duction.
1910.	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
New England.....	7.1	4.1	1.5	4.2	1.1
Middle Atlantic.....	21.0	12.6	6.1	10.2	36.9
East North Central.....	19.8	23.4	18.6	26.2	56.3
West North Central.....	12.7	25.8	34.4	27.5	1.7
South Atlantic.....	13.3	8.8	10.1	7.7	.2
East South Central.....	9.1	7.9	9.2	8.5	(¹)
West South Central.....	9.5	10.9	12.2	8.3	.1
Mountain.....	2.9	2.5	3.3	2.2	.8
Pacific.....	4.6	4.0	4.6	5.2	2.9
Total, United States.....	100.0	100.0	100.0	100.0	100.0
1900.					
New England.....	7.4	5.2	2.0	6.2	2.3
Middle Atlantic.....	20.3	15.2	7.5	15.7	47.3
East North Central.....	21.0	23.1	20.9	27.0	40.3
West North Central.....	13.6	26.4	32.7	27.3	4.6
South Atlantic.....	13.8	8.1	11.1	6.2	.2
East South Central.....	9.9	7.4	9.7	6.6	.1
West South Central.....	8.6	9.6	9.6	5.9	.2
Mountain.....	2.2	1.9	2.0	1.4	1.6
Pacific.....	3.2	3.1	4.5	3.7	3.4
Total, United States.....	100.0	100.0	100.0	100.0	100.0
1890.					
New England.....	7.5	5.0	3.0	6.4	3.5
Middle Atlantic.....	20.2	15.3	8.8	18.1	50.7
East North Central.....	21.4	22.7	22.0	27.1	36.5
West North Central.....	14.2	27.2	29.5	26.8	6.4
South Atlantic.....	14.1	8.3	11.7	6.7	.2
East South Central.....	10.2	8.0	10.0	7.1	.1
West South Central.....	7.5	9.2	8.6	4.2	.1
Mountain.....	1.9	1.3	1.5	.7	.3
Pacific.....	3.0	3.0	4.9	2.9	2.2
Total, United States.....	100.0	100.0	100.0	100.0	100.0
1880.					
New England.....	8.0	6.0	4.6	8.2	5.0
Middle Atlantic.....	20.9	19.6	11.7	26.2	57.0
East North Central.....	22.3	24.0	26.5	29.8	32.5
West North Central.....	12.3	19.4	21.5	17.7	3.1
South Atlantic.....	15.2	10.3	12.7	6.0	.3
East South Central.....	11.1	9.2	10.8	6.4	.1
West South Central.....	6.7	8.1	6.7	2.8	(¹)
Mountain.....	1.3	1.0	.8	.4	.3
Pacific.....	2.2	2.4	4.7	2.5	1.7
Total, United States.....	100.0	100.0	100.0	100.0	100.0
1870.					
New England.....	9.0	7.2	6.4	9.7	10.0
Middle Atlantic.....	22.9	24.5	15.4	34.3	63.9
East North Central.....	23.7	25.2	29.1	30.4	22.0
West North Central.....	10.0	11.7	12.4	11.3	1.3
South Atlantic.....	15.2	11.2	16.0	5.5	.2
East South Central.....	11.4	9.3	12.8	5.3	.3
West South Central.....	5.3	7.4	3.6	1.3	(¹)
Mountain.....	.8	.9	.3	.3	.1
Pacific.....	1.7	2.6	4.0	1.9	2.2
Total, United States.....	100.0	100.0	100.0	100.0	100.0

¹ Less than 0.05 of 1 per cent.

RELATION OF IMPROVED LAND TO POPULATION.

By comparing the improved land with the population we get somewhat of a measure of available food in each geographic division. For the United States as a whole there was 0.3 of an acre more per person in 1910 than in 1870, but nearly 0.5 of an acre less than in 1880. For the last three censuses the number has been growing smaller. The number of acres of improved land per person in New England was nearly 3.5 in 1870, but in 1910 it was slightly over 1.1. For the Middle Atlantic States it had decreased from 3.3 to 1.5 acres. The decrease in the East North Central States began in 1880 and in the South Atlantic in 1870. The West North Central States comprise the only group showing an increased number of acres per person for every census since 1870.

RELATION OF DAIRY COWS TO POPULATION.

The number of dairy cows per 1,000 persons gives us a rough estimate of the available supply of dairy products, but since there is such a marked variation in the average yield of milk per cow it is only an approximate measure. For the United States, as a whole, the changes between 1870 and 1910 have been but slight, amounting to 7 cows per 1,000 persons. The maximum number was reached in 1890. However, the maximum number of cows in the New England States was in 1880, and in the Middle Atlantic and Pacific in 1870. The number in the other geographic divisions has not shown a steady tendency in any one direction.

In considering the changes in dairy cows, it must be realized that the census definition, the conception of what comprised dairy cows, and the age at which they began to be included as such varied with the different censuses.

TABLE 4.—*Number of dairy cows per 1,000 population, by geographic divisions.*

Geographic division.	Number of dairy cows per 1,000 population.				
	1910	1900	1890	1880	1870
New England.....	128.5	159.8	174.9	186.2	184.2
Middle Atlantic.....	134.5	168.4	199.0	232.8	248.6
East North Central.....	264.6	247.9	278.4	266.9	246.3
West North Central.....	457.8	437.6	502.5	391.6	271.3
South Atlantic.....	148.5	132.5	154.6	168.6	171.0
East South Central.....	193.6	167.5	204.1	205.1	189.7
West South Central.....	256.1	250.3	320.1	300.5	324.7
Mountain.....	195.4	196.8	180.1	191.2	264.8
Pacific.....	197.1	222.2	265.9	266.6	339.8
Total, United States.....	224.3	225.5	262.3	248.1	231.7

PER CAPITA PRODUCTION OF BUTTER AND CHEESE.

For the United States, as a whole, in 1910, the amount of butter produced per capita was greater than in 1870 and in 1880, but in 1890 and 1900 the average production per capita was 2 pounds less

than in 1910. In the Southern and Western States the general tendency is for the per capita production to increase, while in the New England and Middle Atlantic States the average is decreasing. There are several factors entering into these changes. The principal ones being changes in population, in dairy cows, in average yields of milk per cow, and in the relative proportion of the total production used for making butter. Changes in the average yield of milk and the relative amounts of milk used raw for human consumption will be discussed later. If the average production per capita for the United States represents the actual average consumption in all the geographic divisions, an average greater or smaller than this amount would represent a surplus or deficit. Using this basis, the New England and Middle Atlantic States began to have a deficit of butter in 1890. The North Central and Pacific States have always had a surplus.

TABLE 5.—Average production of butter and cheese per capita, by geographic divisions.

Geographic division.	1910	1900	1890	1880	1870
BUTTER.					
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
New England.....	10.5	16.5	16.4	16.4	14.2
Middle Atlantic.....	8.6	15.1	17.1	20.1	20.0
East North Central.....	23.2	25.2	24.3	21.4	17.1
West North Central.....	38.2	39.3	36.2	23.2	15.1
South Atlantic.....	10.3	8.9	9.1	6.4	4.9
East South Central.....	16.3	13.0	13.2	9.2	6.2
West South Central.....	15.4	13.6	10.6	6.8	3.3
Mountain.....	13.2	12.2	7.2	4.9	4.3
Pacific.....	20.2	22.6	18.8	18.0	14.5
Total, United States.....	17.6	19.6	19.1	16.1	13.3
CHEESE.					
New England.....	0.6	1.2	1.9	3.0	4.7
Middle Atlantic.....	6.1	9.1	10.2	13.2	11.8
East North Central.....	9.9	7.5	7.0	7.0	3.9
West North Central.....	.5	1.3	1.8	1.2	.6
South Atlantic.....	(¹)	.1	(¹)	.1	(¹)
East South Central.....	(¹)	(¹)	(¹)	(¹)	(¹)
West South Central.....	.1	.1	(¹)	(¹)	.1
Mountain.....	1.0	2.8	.6	.9	.6
Pacific.....	2.2	4.2	3.1	3.8	5.2
Total, United States.....	3.5	3.9	4.1	4.8	4.2

¹ Less than 0.05 of 1 per cent.

The cheese production has always been highly localized in the Middle Atlantic and East North Central States. In the Middle Atlantic States the per capita production is decreasing, while the reverse is true for the East North Central. By comparing the number of acres of improved land with the dairy cows, an approximate index of the relative importance of dairy farming can be obtained. The smaller the number of acres per cow, the more important seems dairying in the system of agriculture. In the North Atlantic, East North Central,

and Pacific States the number of acres per dairy cow is decreasing; in other words, dairy farming is becoming more important as an agricultural industry. In the West South Central and Mountain States, other types of farming increase faster than dairying.

PRODUCTION OF BUTTER PER COW.

During the last 40 years the average quantity of butter produced per cow has increased 30 pounds. This fact must not be taken as a measure of the increase of the productivity of dairy cows, for the relative quantity of the total milk production used for cheese, or consumed raw, may have varied considerably. In the New England and Middle Atlantic States the production of butter, compared with the total number of dairy cows, was lower in 1910 than in any census year since 1870. This indicates that a larger quantity of the milk produced is being used for other purposes. Another interesting fact is that in all of the southern and western States the average production per cow is increasing. For cheese, the average production in the East North Central States has been increasing, while in the Middle Atlantic the tendency is toward a decline.

The average yields of milk per cow, as obtained from the last three censuses, have been obtained by somewhat different methods, so that comparison of one census with another can not be made with any degree of accuracy. One fact, however, appears in all three—that is, the average production in the New England, Middle Atlantic, and East North Central is much larger than that of the Southern States. It also seems that the production in the Pacific and Mountain States is increasing.

FACTORY PRODUCTION OF BUTTER AND CHEESE.

Not only have there been marked changes in the yield of butter and cheese and milk per cow and per person, but in the last 40 years cheese manufacture has changed from a farm operation to a factory system. Butter production is rapidly moving in the same direction. In 1870, 33 per cent of the total cheese made in the United States was produced on farms; and in 1910, only 3 per cent. In 1870 all the butter was produced on farms, but in 1910 only a little over 60 per cent. It can readily be realized what a change the introduction of the factory system has made in the dairy industry. These changes have taken place where the dairy industry is most intense. There has not been developed to any great extent in the United States a method whereby the factory system of making butter and cheese can be carried on where the number of cows is small.

URBAN POPULATION AND DEMAND FOR MARKET MILK.

In 1910 there were 50 cities of 100,000 inhabitants or more, of which 19 were in the North Atlantic States and 15 in the North Central States. Of the cities which had 2,500 inhabitants or more, 861 out of a total of 2,405 were in the North Atlantic States and 805 in the North Central States.

This calls attention to the fact that the demand for market milk is greater in these two geographic divisions. Looking at the same fact from another point of view, in the New England States 5 out of 6 persons live in cities of 2,500 inhabitants or more. In the Middle Atlantic, 7 out of 10; in the East North Central, 1 out of 2, and in the West North Central, 1 out of 3. These ratios call attention to the demand that there must be for market milk.

It should also be remembered that there are a large number of farms in the United States where no dairy cows are kept, and there are also a large number of people living in cities or small towns of less than 2,500 inhabitants. A larger percentage of the farms of the North Atlantic and North Central States report dairy cows than the other geographic divisions. In the South the percentage of farms reporting dairy cows and the average number of cows per farm is small.

In 1900 and 1910 the census gave data from which the quantity of dairy products not sold off farms could be obtained. From these data it is estimated that 58 per cent of the milk produced in 1910 was used to make factory butter and cheese, or for other uses off of the farm. A similar percentage for 1900 was 69. Of all the butter and cheese made on farms a decreasing percentage was sold; that is, the production of butter and cheese on farms is primarily for home consumption. These changes were more marked in the North Atlantic, East North Central, and Pacific States than in the other geographic divisions. This calls attention to the point made above, that the manufacture of dairy products on farms is decreasing most rapidly where the dairy industry is most important.

DISPOSAL OF DAIRY PRODUCTS.

CHARACTERISTICS OF DIFFERENT REGIONS.

In the North Atlantic, North Central, and Pacific States dairying is carried on primarily for the sale of milk rather than for the manufacture of butter on the farm. In the New England and Middle Atlantic States it is generally sold as market milk; while in the North Central States most of it is sold on the basis of its butter-fat content, the greater part of it going to butter and cheese factories.

In 1910 the census returns show the number of farms reporting dairy products as well as the number reporting sales. Thus it is possible to compute the average production as well as the average sales per farm. Such a computation brings out in a striking manner the fact that the average quantity of milk sold per farm of those reporting sales was larger than the average quantity produced per farm of those farms reporting production. This is because the large dairy farms that sell milk constitute a large proportion of those upon whose reports the average sales are computed, while average production is based upon all farms reporting milk production. A similar comparison for butter brings out the fact that the average production for farms showing butter production is larger than the average sale for farms reporting sales; that is, farms of both small and large production sell butter, whereas the farms selling milk consist in large proportion of farms of large production.

DAIRY PRODUCE AS A PRINCIPAL SOURCE OF INCOME.

In 1900, farms were classified according to the principal sources of income. The average number of cows per farm which reported that the principal income was from dairy products ranged from 12 per farm in the Pacific and Middle Atlantic States to less than 5 in the East North Central.

FARM CONSUMPTION OF BUTTER.

If we take the total quantity of butter reported as produced on farms and subtract from it the quantity reported as sold, we have practically the amount of butter consumed on farms. By this method it is estimated that both in 1900 and 1910 the annual consumption averaged 153 pounds per farm. Whether this is the actual average or not can not be proved, but it differs considerably from a similar average obtained by another method which will be shown later in the bulletin.

CONSUMPTION OF MILK IN NEW YORK CITY.

One of the largest factors in determining the consumption of milk after it leaves the farm is the number of people living in cities and towns. In order that a clear conception may be obtained of the influence of market milk upon butter and cheese production, a study of the milk supply of several large cities might be of interest. Prior to 1842 practically all of the milk consumed in New York City was brought by wagons from the surrounding counties. In 1842, when the Erie Railroad was under construction, one of the New York City milkmen began to ship milk from Orange County. This milk proved to be of such good quality that the traffic spread rapidly. In a few years the Harlem division of the New York Central began to haul milk from the counties on the west bank of the Hudson River. At

the same time the Newburgh, Dutchess, and Connecticut branch of the Central New England was shipping milk to New York City over the Hudson River branch of the New York Central. A few years later the New York, New Haven & Hartford was bringing milk from the New England States to supply the New York market. In 1870 the Delaware, Lackawanna & Western received small consignments of milk on its Sussex branch in New Jersey, and in the same year the New York, Ontario & Western started its first milk train from Bloomingburg, N. Y. Practically all of the railroads had their farthest point from New York within the 100-mile limit, except that the Harlem was bringing milk from Rutland, Vt., a distance of 240 miles. There was very little change in the areas from which milk was obtained until 1890. In that year the New York, Ontario & Western extended its service to Walton, N. Y., a distance of 179 miles. Shortly after 1890 several other railroads started milk trains. The Lehigh Valley established this service with Dryden, N. Y., as a terminus. In 1893 the Delaware & Hudson was receiving milk and forwarding it to New York City over the Delaware, Lackawanna & Western. In 1890 the West Shore extended its service beyond Albany, with Syracuse as a starting point, and two years later the Hudson River branch of the New York Central extended its service to the same point. By 1910 many of the points from which milk was shipped to New York City were over 300 miles distant. There were no new railroads to enter this service, but those already carrying milk had extended their lines so that it was bounded by the Canadian boundary line on the north and within a short distance of Buffalo on the west.

TABLE 6.—*Number of gallons of milk and cream received at New York City (cream not reduced to terms of milk).*

Year.	New York Central R. R.				Delaware, Lackawanna & Western R. R.	Erie R. R.	New York, Ontario & Western R. R.	Lehigh Valley R. R.
	N. Y. Central (long haul).	Harlem.	New York & Northern.	Total.				
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
1900.....	11,279,010	5,981,770	1,304,050	18,564,830	16,739,980	16,703,010	16,158,900	5,836,290
1901.....	14,191,800	5,933,620	1,134,580	21,260,000	16,525,320	17,943,170	16,610,600	6,458,920
1902.....	17,502,640	5,565,960	1,194,710	24,263,310	17,104,600	17,320,590	18,368,410	7,102,310
1903.....	18,682,620	5,409,170	1,241,070	25,332,860	18,409,950	18,837,990	19,165,470	7,964,170
1904.....	21,195,240	4,409,180	801,930	26,406,350	20,575,930	20,226,180	21,123,670	8,615,550
1905.....	24,358,300	3,394,700	.....	27,753,000	22,993,070	21,302,910	21,630,110	10,881,080
1906.....	30,193,520	2,465,050	.....	32,658,570	25,155,000	22,123,440	22,212,770	13,017,580
1907.....	33,578,340	3,374,540	.....	36,952,880	25,892,470	24,261,590	22,682,530	14,029,270
1908.....	33,204,810	6,038,080	.....	39,242,890	25,991,090	26,106,260	21,282,670	14,033,880
1909.....	36,285,920	7,697,570	.....	43,983,490	26,464,030	24,330,300	23,706,770	14,466,650
1910.....	40,570,380	10,777,580	.....	51,347,960	27,776,360	24,133,760	23,283,530	15,604,570
1911.....	44,584,190	11,190,430	.....	55,774,620	28,732,850	26,312,810	22,943,150	17,606,580
1912.....	44,832,700	12,051,120	.....	56,883,820	30,693,750	27,004,950	24,953,260	18,216,220
Average:								
1885-1899.....	.....	.....	.....	14,074,436	2,104,362	15,029,436	6,048,940	.....
1900-1904.....	.....	5,566,660	3,718,802	12,285,468	12,007,956	16,998,694	9,926,792	529,794
1905-1909.....	705,592	7,829,584	1,541,072	10,076,248	19,975,436	15,942,236	14,650,162	3,075,194
1900-1901.....	16,570,262	5,459,940	1,135,268	23,165,470	17,873,156	18,206,188	18,285,410	7,195,448
1905-1909.....	31,524,176	4,509,976	.....	36,094,154	25,209,132	23,624,900	22,182,970	13,285,632

TABLE 6.—*Number of gallons of milk and cream received at New York City (cream not reduced to terms of milk)*—Continued.

Year.	West Shore R. R.	New York, Susque- hanna & Western R. R.	New York, New Haven & Hartford R. R.	Ramsdell Boat Line.	Central R. R. of New Jersey.	Long Island R. R.	Other sources.	Total.
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
1900.....	6,428,330	7,562,400	4,000,580	3,018,910	903,690	.....	2,190,000	98,116,920
1901.....	6,399,280	7,400,910	4,161,560	2,380,030	752,440	.....	2,199,460	102,091,690
1902.....	6,401,050	7,273,030	4,022,210	2,274,530	590,900	.....	2,190,000	106,910,940
1903.....	7,146,940	7,686,200	4,327,370	2,591,480	601,440	.....	2,190,000	114,253,870
1904.....	7,675,950	7,887,610	4,845,820	2,172,890	658,480	.....	2,196,000	122,384,430
1905.....	9,016,790	7,690,230	4,950,650	2,192,930	626,510	.....	2,190,000	130,597,280
1906.....	9,506,040	8,096,880	6,718,760	2,595,600	830,850	.....	2,190,000	145,105,490
1907.....	8,387,060	8,010,240	6,189,850	1,588,720	420,180	.....	2,196,000	150,610,790
1908.....	7,957,190	7,490,820	6,006,120	1,309,380	171,640	.....	2,380,000	151,971,930
1909.....	7,722,380	7,297,820	6,188,750	1,000,880	.....	.....	2,555,000	157,626,050
1910.....	8,047,520	7,348,910	6,303,250	957,930	.....	.....	2,555,000	167,358,790
1911.....	7,492,780	7,310,450	6,746,970	1,034,750	.....	.....	2,555,000	176,509,960
1912.....	7,971,610	7,180,420	5,619,700	1,147,880	.....	.....	2,562,000	182,233,610
Average:								
1885-1889.	2,974,892	5,087,000	3,911,264	1,503,784	1,772,282	1,519,776	3,302,650	57,328,822
1890-1894.	5,146,400	5,862,474	2,402,730	2,667,980	1,038,752	1,106,110	2,373,150	72,346,300
1895-1899.	6,376,398	6,991,500	4,193,730	2,550,890	953,214	282,016	2,186,900	87,253,924
1900-1904.	6,810,310	7,562,030	4,271,508	2,487,568	701,390	.....	2,193,092	108,751,570
1905-1909.	8,517,892	7,717,198	6,010,832	1,737,502	409,836	.....	2,302,200	147,182,308

CHANGES IN POPULATION AND MILK RECEIPTS OF NEW YORK CITY.

In 1886, 5,500,000 forty-quart cans of milk and cream were received in New York City. In 1911 this amount had increased to over 18,000,000, or an increase of 200 per cent in 25 years. In 1880 the population of New York City was 1,800,000; in 1890, 2,500,000, and in 1910, 4,800,000. It is evident, therefore, that the increase in population has not been as rapid as the increase in milk receipts. In other words, apparently there has been an increase in the per capita consumption. The quantity of milk received in New York in 1910 would make 50,000,000 pounds of butter, or 130,000,000 pounds of cheese, while the receipts in 1890 would make 19,500,000 pounds of butter, or 52,000,000 pounds of cheese; thus the increase for these 20 years in the milk received in New York City would be equivalent to 30,000,000 pounds of butter, or 78,000,000 pounds of cheese. According to the census for these years the actual decrease in production for New York State was 42,000,000 pounds of butter and 19,000,000 pounds of cheese, and in Pennsylvania, 5,000,000 pounds of butter and 7,000,000 pounds of cheese; or for the two States the decrease in production in the twenty years amounted to 47,000,000 pounds for butter and 26,000,000 pounds for cheese. Therefore New York City has not been the only factor in decreasing the butter and cheese production, but the demand of other cities for market milk has caused a decrease in this production equivalent to about 100,000,000 gallons.

INFLUENCE OF MARKET MILK UPON BUTTER AND CHEESE PRODUCTION.

Thus we see that prior to 1890 most of the railroad milk consumed in New York came from counties on the eastern bank of the Hudson River and Orange and Sullivan Counties on the west. After 1890

the railroads reached out into the counties where butter and cheese manufacturing had become prominent. In order to determine what was the influence of this competition of market milk with the milk for butter and cheese production, a detailed study of the changes in a few counties might be of value. In the counties where milk shipment began early, as in Westchester, Putnam, Dutchess, and Columbia, butter and cheese production on farms never became important, and in recent years a decreasing percentage of the total milk produced has been used for the production of butter and cheese, either on the farm or in the factory. Although there was a tendency for the number of cows to increase between 1880 and 1890, in most instances the number has been decreasing in recent years.

Delaware County is a county in which the introduction of butter and cheese factories and the shipping of market milk took place at about the same time. In 1890, 6,600,000 pounds of butter was produced on farms; in 10 years it decreased to 6,000,000, and the factory production amounted to 2,000,000. In 1910 the farm production was less than 1,000,000 pounds, and the factory production had increased so that in some years it amounted to over 5,000,000 pounds. In the meantime milk received by the condenseries and milk-shipping stations had reached nearly 25,000,000 gallons annually. The number of dairy cows in Delaware County continues to increase. In 1860 there were over 38,000; in 1880, 58,000; in 1910, 78,000.

Herkimer and Chenango are counties where factory-cheese production became established early in its development, and market milk did not begin to compete until after 1890. Here, also, is found a marked decrease in the production of farm butter, and apparently a slight decline in the manufacture of butter and cheese, but the amount of milk received by milk-shipping stations continues to rise. The number of dairy cows reached its maximum in 1880 and shows a decline since that census.

Although New York is the only State in the North Atlantic group which showed an increase in dairy cows in 1910 over 1900, the increase was very slight and due primarily to the spreading of the dairy industry into areas formerly prominent for their grain production. For the State as a whole, the most marked change in the dairy industry was a decrease of farm-made butter from 75,000,000 pounds to 23,000,000 pounds, while there was an increase of only a little over 5,000,000 pounds in factory-made butter. The decrease in cheese production amounted to 25,000,000 pounds. Consequently a large part of the milk formerly used to produce butter and cheese on farms is now sold to be consumed raw.

MILK SUPPLY OF BOSTON.

Prior to 1870 all of the milk consumed in Boston came from a distance of not more than 65 miles. By 1890 the Boston & Maine Railroad was bringing milk from a distance of 150 miles, and in 1910, 275

miles. Prior to 1900 all of the milk for Boston carried over the New York, New Haven & Hartford Railroad came from stations within 34 miles of the city. But the demand increased so that the farthest shipping points were 85 miles distant in 1900 and 210 in 1910. Several of the shipping points for Boston are in regions from which milk is shipped to New York City also, and therefore these two cities are competitors at these points.

MILK SUPPLY OF PHILADELPHIA.

Prior to 1870, Philadelphia was receiving its milk from an area within a radius of 50 miles of the city, and the greater part of the milk received was transported by railroads. Prior to 1910 the farthest points on the Pennsylvania Railroad system from which milk was shipped to Philadelphia were near Harrisburg and Reading, in Pennsylvania, and Milford, Princeton, Hightstown, Bridgeton, and Salem, in New Jersey. But in 1911 the area was extended until it reached to points in New York State within a few miles of Buffalo. The Reading system in 1910 was drawing its milk for Philadelphia over practically as large an area as was the Pennsylvania Railroad system.

TABLE 7.—*Number of quarts of milk received at Philadelphia, 1890-1911.*

Year.	Pennsylvania R. R. system.	Philadelphia & Reading R. R.	Baltimore & Ohio R. R.	Wagons (estimated).
	<i>Quarts.</i>	<i>Quarts.</i>	<i>Quarts.</i>	<i>Quarts.</i>
1900.....	39,820,550	39,490,498	6,029,436	7,200,000
1901.....	42,041,944	37,586,960	6,268,120	7,200,000
1902.....	44,295,196	36,836,840	6,502,916	7,200,000
1903.....	47,984,643	38,842,186	7,015,284	7,200,000
1904.....	49,777,425	39,064,700	6,986,160	6,000,000
1905.....	51,438,909	41,686,952	7,640,540	6,000,000
1906.....	54,974,613	49,534,862	9,440,360	6,000,000
1907.....	56,284,822	53,399,354	11,022,260	6,000,000
1908.....	58,513,720	55,434,606	11,285,260	6,000,000
1909.....	62,678,151	52,746,857	13,319,444	6,000,000
1910.....				
1911.....	67,883,718	62,212,211	12,788,504	4,800,000
Averages:				
1890-1894.....	37,716,398	36,570,061	5,743,388	10,260,000
1895-1899.....	38,413,831	35,063,470	6,275,870	8,280,000
1900-1904.....	44,783,952	38,364,237	6,560,383	6,960,000
1905-1909.....	56,778,043	50,560,526	10,541,573	6,000,000

Year.	Trolley lines at 63d and Market Streets.	Lehigh Valley R. R. via Philadelphia & Reading. ¹	Adams Express Co.	United States Express Co.	Total.
	<i>Quarts.</i>	<i>Quarts.</i>	<i>Quarts.</i>	<i>Quarts.</i>	<i>Quarts.</i>
1900.....		10,015,824			102,556,308
1901.....		10,340,320			103,437,344
1902.....		9,885,190			104,720,142
1903.....		10,200,920			111,243,033
1904.....		10,069,080			111,897,365
1905.....	3,818,829	9,815,740			120,400,970
1906.....	4,120,597	5,580,950			129,651,382
1907.....	4,378,952	898,600	3,157,560	789,640	135,931,188
1908.....	5,667,660		2,629,510	832,240	140,362,996
1909.....	6,899,821		3,697,770	652,820	145,994,863
1910.....					
1911.....	9,098,066		5,290,520	427,560	162,500,579
Averages:					
1890-1894.....		2,152,200			92,442,047
1895-1899.....		8,158,288			96,191,459
1900-1904.....		10,102,267			106,770,838
1905-1909.....	4,977,172	3,259,058	1,896,968	454,940	134,468,280

¹ Originating at stations on the Lehigh Valley Railroad and forwarded to Philadelphia over the Philadelphia & Reading Railroad.

FLUCTUATIONS IN PRICES OF BUTTER AND OF MARKET MILK.

By comparing the prices for milk with those paid for butter on the same market, somewhat of a line of the influence of one upon the other can be obtained. By comparing the wholesale prices of milk and butter on the New York market for the last 35 years, it is noted that in only three years has there been a rise or a drop in the price of one without an accompanying change in the price of the other. In the three years mentioned, the price of butter dropped, but the price of milk did not. When a comparison is made of the number of quarts of milk it would require for a pound of butter, it is found that for the five years prior to 1895 it took 9.31 quarts to buy 1 pound of butter, and for the five years prior to 1910, 8.4 quarts. Even this is 0.15 below the average for 1885-1889, the lowest period being between 1875 and 1895. It was about 1890 that the North Atlantic States were not producing as much butter as they were consuming, and the price began to rise. To obtain milk for consumption raw, milkmen had to pay above the factory prices, so that it took fewer quarts of milk to buy a pound of butter.

TABLE 8.—*Prices of milk and butter in New York City.*

Year.	Average price of—		Amount of milk equal in value to 1 pound of butter.
	Butter.	Milk.	
	<i>Cents.</i>	<i>Cents.</i>	<i>Quarts.</i>
1901.....	21.6	2.62	8.24
1902.....	24.8	2.88	8.61
1903.....	23.48	2.88	8.15
1904.....	21.75	2.75	7.91
1905.....	24.64	2.89	8.53
1906.....	24.67	3.01	8.20
1907.....	28.14	3.35	8.40
1908.....	27.00	3.29	8.21
1909.....	29.21	3.38	8.64
1910.....	30.13	3.68	8.19
1911.....	26.77	3.36	7.97
1912.....	31.38	3.68	8.53
Average:			
1865-1869.....	38.94	5.12	7.61
1870-1874.....	32.96	4.04	8.16
1875-1879.....	27.56	3.03	9.10
1880-1884.....	27.70	3.07	9.02
1885-1889.....	23.62	2.76	8.56
1890-1894.....	24.94	2.68	9.31
1895-1899.....	19.86	2.42	8.21
1900-1904.....	22.81	2.77	8.23
1905-1909.....	26.73	3.18	8.41

CHICAGO'S RECEIPTS AND SHIPMENTS OF BUTTER.

Prior to 1875 the receipts of butter at Chicago were less than 40,000,000 pounds. The average receipts for 1890 to 1894 were 136,000,000 pounds, and 15 years later this quantity had more than doubled. A small proportion of this butter was consumed within the city.

Prior to 1875, shipments of butter amounted to less than 20,000,000 pounds, but in the next five years they had reached 35,000,000 pounds and in 1911, 285,000,000 pounds. Of the 1910 shipments 75 per cent were forwarded over "eastern lines" and, presumably, were consumed in the North Atlantic States. In 1911 the shipments of butter over "eastern lines" exceeded the entire farm and factory production in the North Atlantic States.

TABLE 9.—Receipts and shipments of butter at Chicago, 1870-1911.

Year.	Receipts.			
	Chicago & North Western Ry.	Illinois Central Ry.	Chicago, Rock Island & Pacific Ry.	Chicago, Burlington & Quincy R. R.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1900.....	72,341,368	15,091,300	16,945,148	17,042,055
1901.....	67,504,965	16,157,000	12,953,692	22,440,240
1902.....	70,756,785	15,545,900	9,630,909	21,511,390
1903.....	74,394,032	14,512,200	14,839,751	19,697,800
1904.....	74,163,297	18,707,620	20,605,673	18,529,708
1905.....	77,386,276	20,039,400	40,318,260	23,272,195
1906.....	62,352,403	23,682,800	33,802,475	33,694,683
1907.....	71,327,391	22,968,265	27,794,396	47,907,105
1908.....	82,140,322	19,774,100	28,995,256	65,287,598
1909.....	79,079,399	19,419,500	17,426,093	57,144,541
1910.....	105,892,369	16,818,200	19,870,309	57,429,012
1911.....	106,174,300	10,652,300	20,675,900	58,418,200
Average:				
1870-1874.....	5,980,855	-----	1,596,560	5,047,724
1875-1879.....	14,830,358	6,705,835	2,355,528	6,055,937
1880-1884.....	20,859,824	11,512,078	8,596,308	7,557,451
1885-1889.....	34,987,966	14,630,295	13,680,105	12,810,383
1890-1894.....	35,601,770	12,574,276	21,772,140	12,145,476
1895-1899.....	67,707,672	16,332,074	30,992,093	20,027,476
1900-1904.....	71,832,089	16,002,804	14,995,035	19,844,239
1905-1909.....	74,467,158	21,176,813	29,667,296	45,461,224

Year.	Receipts.			Total shipments.
	Chicago, Milwaukee, & St. Paul Ry.	Other routes.	Total.	
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1900.....	89,586,700	33,378,619	244,385,190	208,536,699
1901.....	98,205,060	36,548,286	253,809,243	245,488,028
1902.....	65,649,800	36,137,758	219,232,542	201,787,285
1903.....	63,108,400	45,480,301	232,032,484	197,620,859
1904.....	62,446,200	48,671,648	243,124,146	249,359,694
1905.....	65,252,973	45,645,699	271,914,803	254,130,889
1906.....	48,679,084	46,436,653	248,648,098	252,807,516
1907.....	47,947,342	45,770,143	263,714,642	252,005,932
1908.....	74,041,760	46,455,746	316,694,782	269,178,313
1909.....	71,048,129	40,429,173	284,546,835	235,648,837
1910.....	71,490,137	47,485,473	318,985,500	266,288,900
1911.....	64,326,100	74,685,600	334,932,400	285,685,400
Average:				
1870-1874.....	7,510,102	2,702,835	40,160,595	37,234,087
1875-1879.....	21,493,212	1,842,147	71,861,020	68,644,705
1880-1884.....	30,302,740	7,093,265	113,504,754	114,995,773
1885-1889.....	38,901,702	15,449,152	136,444,516	148,425,031
1890-1894.....	75,910,798	9,532,719	220,502,832	200,973,969
1895-1899.....	75,799,232	40,043,322	238,516,721	220,558,513
1900-1904.....	61,393,858	44,947,483	277,103,832	252,754,297

RECEIPTS OF BUTTER AT NEW YORK CITY.

The receipts of butter at New York City amounted to 75,000,000 pounds in 1880 and increased to 125,000,000 in 1910. At the earlier date the shipments east of Chicago amounted to less than 60,000,000 pounds, so that New York City could not have been entirely dependent upon butter shipped from Chicago. However, in 1911 there were shipped east 240,000,000 pounds, or nearly twice the amount received at New York. Therefore, it is readily seen that western butter must go into other eastern markets as well as New York City.

Taking the difference between the average per capita production for the United States as a whole and the average per capita consumption, the North Atlantic States would show a deficit of nearly 200,000,000 pounds; while the North Central States would have a surplus of 325,000,000 pounds; so it will be seen that the latter group supplies the deficit, not only for the Northern Atlantic States, but also for other parts of the country.

SPECIAL STUDY OF CONSUMPTION OF MILK AND BUTTER.

QUANTITY OF MILK USED ON FARMS.

A circular letter was sent to correspondents of the Bureau of Crop Estimates asking for the number of persons in a household and the average daily consumption of milk and of butter. Replies to this letter indicated that the average person in a farm household consumes about three-fourths of a quart of milk per day. This includes milk used for cooking, as well as that consumed raw or used with tea or coffee. The average household of the farmer was found to be 5.3 persons, so that altogether they consumed over 4 quarts per day. If the average consumption per farm for the year is multiplied by the total number of farms reporting dairy cows it shows that nearly 8,000,000,000 quarts of milk are used on farms for consumption raw. This amount nearly equals the quantity received by butter, cheese factories, and condenseries.

TABLE 10.—*Milk consumption on farms.*

Geographic division.	Average number of members per household.	Average milk consumed—		Farms reporting dairy cows.	Estimated total milk consumption on farms.
		Per household per year.	Per capita per year.		
		<i>Quarts.</i>	<i>Quarts.</i>	<i>Number.</i>	<i>Quarts.</i>
New England.....	5.3	1,425	271	147,028	209,514,900
Middle Atlantic.....	4.6	1,059	231	400,473	424,100,907
East North Central.....	4.7	1,111	238	1,009,479	1,121,531,169
West North Central.....	5.4	1,436	267	989,135	1,420,397,860
South Atlantic.....	5.3	1,568	297	794,716	1,246,114,688
East South Central.....	5.5	1,780	326	815,423	1,451,452,940
West South Central.....	5.9	1,862	317	724,466	1,348,955,692
Mountain.....	6.2	1,986	319	120,328	238,971,458
Pacific.....	4.9	1,364	276	139,821	190,715,844
Total, United States.....	5.3	1,488	288	5,140,869	7,651,755,458

BUTTER CONSUMPTION ON FARMS.

Returns from this inquiry also indicate that the average person on the farm consumed a pound of butter every 10 days, or that the average farm family consumed over a half pound per day. If this average per family for the year be multiplied by the total number of farms reporting butter production, it would equal nearly 900,000,000 pounds. An additional question was asked of those correspondents who made butter, namely, "How many quarts of milk does it require to make a pound of butter?" The average for the United States was 9.6 quarts; varying from 8.1 for the West South Central States to 10.7 for the West North Central. If the total sales of butter by farmers is added to the total home consumption as obtained above, and the result multiplied by the average number of quarts of milk necessary to produce a pound of butter, it shows that farmers use at home, for butter, over 12,000,000,000 quarts of milk annually, or over 40 per cent more than was reported by butter and cheese factories and condenseries to the Thirteenth Census.

TABLE 11.—*Butter consumption on farms.*

Geographic division.	Average number of members per household.	Average butter consumed.		Farms reporting butter production.	Estimated total consumption on farms.
		Per household per year.	Per capita per year.		
		<i>Pounds.</i>	<i>Pounds.</i>	<i>Number.</i>	<i>Pounds.</i>
New England.....	5.3	160	30	94,858	15,177,280
Middle Atlantic.....	4.6	182	40	267,085	48,609,470
East North Central.....	4.7	176	38	802,909	141,311,984
West North Central.....	5.4	210	39	841,084	176,627,640
South Atlantic.....	5.3	181	34	772,972	139,907,932
East South Central.....	5.5	190	35	820,015	155,802,850
West South Central.....	5.9	214	36	705,549	150,987,486
Mountain.....	6.2	222	36	101,777	22,594,494
Pacific.....	5.0	158	32	109,036	17,227,688
Total, United States.....	5.3	192	36	4,515,285	868,246,824

TABLE 12.—*Consumption of milk in cities.*

Geographic division.	Cities of 25,000 and over.		Cities of 2,500 and over.	
	Yearly per capita consumption.	Estimated total consumption.	Yearly per capita consumption.	Estimated total consumption.
	<i>Gallons.</i>	<i>Gallons.</i>	<i>Gallons.</i>	<i>Gallons.</i>
New England.....	35,709	115,874,669	35,794	195,268,619
Middle Atlantic.....	33,854	362,598,650	33,270	456,576,620
East North Central.....	29,379	185,551,154	25,397	244,249,832
West North Central.....	20,030	47,623,108	20,888	80,914,180
South Atlantic.....	21,428	40,379,095	20,677	63,936,448
East South Central.....	18,656	16,554,719	18,590	29,264,917
West South Central.....	17,529	17,106,358	17,519	34,292,672
Mountain.....	24,974	11,097,846	22,369	21,194,874
Pacific.....	31,781	54,116,115	31,151	74,211,931
Total, United States.....	29,810	850,901,714	28,151	1,199,910,093

QUANTITY OF MILK CONSUMED IN CITIES.

An inquiry was addressed to the boards of health in all the cities of 2,500 inhabitants or over, asking the average daily receipts of milk in January, April, July, and October. Replies to this inquiry indicates that the average per capita consumption was 28 gallons, or 112 quarts per year; hence the average person in a city consumed less than one-third of a quart of milk per day. The average farm consumption was 288 quarts in the year. If the average per capita yearly consumption is multiplied by the total city population, it shows that cities require 1,000,000,000 gallons per year. Another interesting result shown by these returns was that the consumption was slightly higher in cities of 25,000 inhabitants or over than in smaller cities.

The returns regarding the variation in milk consumption by months were not entirely satisfactory, but seem to indicate that the receipts at the large cities fluctuate less than those of the smaller ones. The fluctuations were generally less than 10 per cent.

MILK CONSUMPTION IN SMALL TOWNS.

Since no data are available to show the consumption in small cities or villages, or on farms not having dairy cows, the total consumption can not be accurately estimated. If the average per capita consumption of milk in the cities of 2,500 or over is applied to the population not on dairy farms, but considered as rural, it would require 600,000,000 gallons per year. If this is added to the quantity of milk received by the butter and cheese factories and condenseries, the quantity required to produce butter and cheese on farms, the quantity used for consumption raw upon farms, and the quantity consumed by cities of 2,500 or over, it would approximate 9,000,000,000 gallons. Of course a large quantity of milk is used for feeding calves in addition. If this total consumption is divided by the total number of dairy cows, whether on farms or not, an average annual production would be obtained of over 400 gallons per cow. The average production, according to the census of 1910, for those cows on farms for which milk production was reported was only 362.

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BULLETIN No. 178

Contribution from the Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C.



March 1, 1915

COOPERATIVE ORGANIZATION
BUSINESS METHODS

By

W. H. KERR, Investigator in Market Business Practice, and
G. A. NAHSTOLL, Assistant in Cooperative Organization
Accounting

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INTRODUCTION.

In the promotion of a cooperative enterprise there is a tendency to look only upon the opportunities of the business itself and the great benefits to be derived therefrom, disregarding the equally important matters concerning the formulation of plans and the adoption of methods for the successful conduct of the business.

There is considerable excellent business literature dealing with special phases of various business activities, but there is very little which deals directly with the business of cooperative agricultural marketing organizations. This bulletin has been prepared to meet the demands for data relating to the business requirements of these organizations. Many of its discussions are somewhat elementary, but there is need for just such discussions, since there are many persons connected with cooperative organizations who are unfamiliar with these questions. This is the first of a series of bulletins the department intends to issue which will deal with the business methods of cooperative agricultural marketing organizations, and it may be termed a general bulletin in that it covers matters of interest to all

forms of these organizations. In the others it is planned to deal with the business requirements of specific classes, such as produce, deciduous-fruit, citrus-fruit, elevator, creamery, and various other organizations, and to present systems of accounts and information of special value to the type of organization for which they are written.

SYSTEMS OF ACCOUNTS.

ACCOUNTING RECORDS NECESSARY.

Accurate records and accounts are essential in the management of every business enterprise, great or small. The failure of many co-operative organizations for marketing farm products has been traced either directly or indirectly to the lack of proper accounting systems.

The very life of a cooperative organization depends on the confidence reposed in it by its members and on their knowledge that the affairs of the organization are conducted in a businesslike manner and that each transaction is recorded clearly and accurately in books of account. Such records will tend greatly to increase confidence. The organizations which keep accurate records will also be in a better position to command the necessary financial assistance from bankers and credit men, when such help is needed, than associations having lax systems of accounting records.

When markets are bad or the quality of the product inferior, causing low prices, the faith of even the most loyal members is often slightly shaken. In such cases assurance can be reestablished quickly by having the records of all transactions in such shape that the members can trace their deliveries through the books from the time they are received by the association to the date of settlement.

WHAT IS SYSTEM?

The fact must be kept in mind that business systems do not consist entirely of forms. The most perfect set of forms ever drawn is worthless without the organized effort to use them properly.

System is organized effort, and every business must be conducted under some sort of prearranged plan, so that there is unity of effort, making each pound of effort expended further the objects of the organization's existence. Care should be taken in choosing a system for a cooperative organization to see that it hangs together, each part being in complete accord with every other.

BOOKKEEPING.

Bookkeeping may be defined as the systematic and chronological recording of financial transactions. It is the medium through which accounting results are obtained. There are two methods of bookkeeping, single entry and double entry.

DOUBLE VERSUS SINGLE ENTRY.

For records of a cooperative organization the double-entry system is the only one worthy of consideration. Accounting for any business based on single entry should be discouraged. The double-entry system is the only one affording a complete check.

"Single entry," as one well-known authority says, "is the recording of business transactions without regard to scientific principles. The term is rightly applied to any method of recording business transactions other than by the double-entry method. It is unscientific because it is incomplete and therefore can not reflect the true condition of affairs or the results from operations."¹

Double entry is the scientific method and provides a complete record of business transactions in such a manner as to show the effects of such transactions upon the assets, liabilities, capital, surplus, and revenue, and also to show the expenses of the business.

The equalization of debit and credit in every transaction, which is secured by all double-entry records, guarantees the mathematical accuracy which is a most important feature.

BOOKKEEPING POSSIBLE WITH FEW BOOKS.

Only two books are absolutely necessary for a complete and systematic record of the financial transactions of a business, the journal and the ledger. The journal presents the record of business transactions in chronological order, while the ledger shows the same classified as to the respective accounts. The great number of books now used as accounting records are but forms of these two books, and the principles of double-entry bookkeeping apply in both cases.

REQUIREMENTS OF A SYSTEM FOR A COOPERATIVE ORGANIZATION.

The first study of a manager should be of the business contemplated and of the best methods for carrying out the objects of the organization. Then a study should be made of the best method of recording the business transactions properly. After such a study, a complete business system should be worked out.

A cooperative organization acts as the agent of the grower in the marketing of his product, and a system for such an organization must not only contain the usual accounting records showing the assets and liabilities, profits and losses, and the receipts and disbursements of cash, but it must show a clear record of each grower's shipments from the time of delivery until payment has been made. The system must be capable of taking care of the maximum volume of business during the height of the shipping season and provide

¹ Bentley, Harry C. *The Science of Accounts*. New York, Ronald Press. See p. 17.

the quickest and most efficient method of returning to the grower the proceeds of his product. It must provide for a record which not only will show every detail, but which is so arranged as to allow instant reference.

Many cooperative organizations have adopted the system of pooling, which necessitates the prorating of returns on like grades of fruit and produce. The record of this pool should therefore be clear as to time, shipments covered, and average prices obtained, so that any discrimination can be shown quickly.

Auxiliary accounts, whether of money or items, should be checked in the same manner as those of the financial system. To be of any useful purpose these records must be absolutely accurate.

NO TWO ORGANIZATIONS EXACTLY ALIKE.

No two organizations in the United States work under exactly the same conditions. Plans of organization, methods of selling, varieties of products, local conditions, and various other things which affect the accounting will be different for each organization. Hence it is necessary for the manager to see that any forms or systems selected are best fitted to conduct his particular business, for every organization will have some peculiarities of its own, which will require the working out of a method best adapted for keeping the record of such transactions.

No cut-and-dried system of forms is ideal for any organization, yet the adding of a column here and there, or some slight change, will often adapt a form to the particular requirements of a business.

Small organizations often adopt bodily the forms of other, perhaps larger, organizations, working under an entirely different plan, thus providing themselves with forms not at all suited to their needs.

ACCOUNTING FORMS.

In the preparation of forms great care should be exercised to include only that which is necessary. Great saving of labor is effected by the use of columnar books. However, to add column after column to any particular book for accounts to which there would be but few entries monthly would only make the book cumbersome and serve to offset some of the advantages to be derived from the use of columnar books.

Forms of statements showing returns or ledger accounts of growers should be so headed and constructed as to be perfectly plain and intelligible at first glance. They should be headed in such a way that growers will know their use immediately, as, for instance, "Grower's receipt," "Statement of returns for fruit shipped by

———.” “Statement of grower’s ledger account.” Also columns should be headed “Charges,” “Credits,” and balances should be designated as “Balance due grower,” “Balance due exchange.”

LABOR-SAVING DEVICES.

There is often a mistaken idea of economy in regard to any expenditure for the installation of an up-to-date accounting system, the employment of competent help, and the introduction of various labor-saving devices. The cost of an adding machine or calculating machine may seem large, but may save its original cost by the elimination of extra help during the first year, providing the volume of business is sufficient to make its use economical. Columnar development, loose-leaf systems, card systems, the carbon copy, have all lessened the routine of the bookkeeper and made modern bookkeeping both possible and economical.

The use of loose-leaf systems will be found of advantage, as this method permits the elimination of dead accounts and the division of labor as the accounting work increases during the heavy shipping season. The use of carbon copies has made it possible to do away with many duplicate entries of the same information. There are numerous devices for reducing the cost of accounting, each of which serves its particular purpose, and any one of which may be admirably adapted for specific purposes in an office.

THE OFFICE MANAGER.

The office of every cooperative organization must be modeled according to the prevailing conditions of the business, and it is necessary to place the office work in charge of a person fully competent and trained to cope with these conditions, thus relieving the general manager of the necessity of handling details.

The time of the general manager is valuable to the business in outlining the large matters of policy and directing all the forces that make for a larger and better concern. He should not be expected to give time to office details when the volume of business is sufficiently large to require as his right-hand man an efficient office manager, one who can successfully carry on the work connected with the records.

The office manager should be an accountant, and it is preferable that he be thoroughly familiar with the type of the organization the office of which he is to direct. This knowledge is the first essential toward making it possible for him to direct others, to give them an understanding of the organization’s business policies, and to keep the office force in harmony with these policies. In the smaller organizations the entire force consists of but one man. Here, as

well as in the larger organizations, knowledge of accounting and of the business principles involved in the particular type of cooperative organization are essential, as the manager in these cases must perform all the accounting duties in addition to those of the general manager. The office manager of the small organization is relatively just as important a personage in helping to promote or defeat the objects of the cooperative scheme as is the office manager of the largest organization.

The office manager should have executive ability and a broad point of view, combined with the ability to perceive the importance of details. He should have the power to direct others and the ability to maintain a happy, harmonious spirit throughout the organization.

In no other business is the quality of courtesy more essential. The office force deals in most cases with members who are part owners of the business, and who in all cases must be treated with courtesy. A spirit of enthusiasm should always be present in the office, in order that the grower may be impressed with the business-like appearance of everything—the activity, the openness of the business, the methods used, and the promptness and accuracy with which the work is done.

The office manager should keep in touch with other organizations and with the progress, development, and improvements in existing practices of cooperative organizations generally, thereby being in a position to take advantage of anything that will be of benefit to the office.

OFFICE EMPLOYEES.

In a great many organizations there is a rush during the marketing season, which usually does not extend over two or three months; this is followed by a season of comparative inactivity. The clerical help can not be retained during the dull season. This necessitates the breaking in of new men each year, and is a very unfortunate feature. One of the greatest employers of office help in this country claims that it costs \$100 in loss of supplies, time, and training by higher salaried employees, in mistakes that must be corrected, etc., to break in each new clerk. If possible, at least all the head men in an office should be retained throughout the year. This applies to the small concerns where the manager and a helper are the only employees.

A great many organizations have introduced separate departments which handle commodities other than those which would come regularly under the head of growers' supplies, for the purpose of keeping the office force intact during the slack season of the year. In the case of some fruit associations this has taken the

form of a wholesale department which deals in a number of lines of merchandise such as are generally handled by wholesale grocers and commission houses; and in the case of grain elevators, lumber and coal and other supplies have been dealt in as side lines. These enterprises are engaged in not only to aid the members in buying these commodities at better prices, but to provide work for the office force when it is not engaged in the work of the regular shipping season. One of the large organizations in New England has established a fertilizer plant in connection with its already extensive dealings in growers' supplies, the business thus created warranting the retention of the entire office force throughout the year.

THE SECRETARY.

The duties of the secretary are usually clearly defined in the by-laws of the organization. He is the recording officer and keeps the corporation books, the minute book, the stock-certificate book, the stock ledger, and the transfer book. He also has charge of, and is responsible for, the seal of the organization.

Various matters involving corporate procedure constantly arise, and for the proper discharge of his duties the secretary should keep himself fully posted. A digest of the statutes of the State relating to corporations, a manual of parliamentary law, and a book on corporate procedure will be found of much assistance. A corporate calendar will also be found of great convenience. This is a calendar of the dates of the meetings of the directors and stockholders and of the dates on which notices for the same must be mailed. It is a comprehensive record of the important corporate formalities that must be attended to at fixed periods, such as the filing of reports, etc. By the use of such a book the secretary can tell at a glance what corporate duties require his attention.

It has been found advisable by some of the larger organizations to confer the titles and duties of secretary and treasurer upon officers other than members of the board of directors. Often the office manager is made both secretary and treasurer, by which arrangement there is no delay in securing signatures to papers when needed and the office force has the necessary authority to complete all business routine.

RECORDS OF MEETINGS.

Corporate meetings, both of shareholders and directors, being held for deliberative purposes, should be conducted according to parliamentary usages. The record of these meetings is the best evidence of the action taken, and other evidence is not admissible until it is shown that the records can not be obtained.

The minute book should contain the original transcript of the constitution and by-laws, a record of the amendments made from time to time, and a full account of the meetings both of stockholders and directors. These minutes should follow in proper order, be approved at the next meeting, and be signed by the proper officers as a certification of such approval.

In order to facilitate reference to the minute book a wide margin should be allowed on the left-hand side of the page, in which the subject can be stated or such other annotations made as will aid in locating the desired information.

The directors must act in a duly called meeting. They have no authority to bind the organization by their individual acts done outside the corporate meetings, and they can not vote by proxy. Unless a provision to the contrary is made, a majority of all the directors constitutes a quorum.

NOTICE OF SHAREHOLDERS' OR MEMBERS' MEETINGS.

The issuing of notices of meetings should be regulated by the by-laws. Notice by publication and through the mail are the most common and best methods. If the meeting is a special one, or if the business to be done is extraordinary or unusual, the notice must state the nature of the business to be transacted. It is best to give notice of adjourned meetings in the same manner as notice of other meetings, as a reminder to members.

TREASURER.

The by-laws should contain measures of safety to regulate the handling of all organization funds. Checks should be placed upon the official actions of the treasurer. Proper accounts should be kept, periodical audits made, and the prompt deposit of all funds and proper vouchers for all disbursements required. In the smaller organizations, where audits by public accountants are seldom made and the manager acts as office manager and bookkeeper, it is well to have the funds handled by a treasurer who is not connected with the office force.

SURETY BONDS.

All persons handling organization funds should be bonded. This bond should be sufficient to cover any loss which is reasonably probable. A surety company bond premium ranges from \$4 to \$7 per \$1,000, and such a bond is superior to a personal bond. It is proper that the organization assume the expense of bonds for officials and employees.

FILING SYSTEMS.

Vertical filing cabinets, either wood or metal, have become standard equipment. These files are equipped with heavy press-board guides for indexing purposes and with folders in which the correspondence is placed. There are several systems of indexing in use; but two, however, the alphabetical and the numerical, need to be considered here.

THE ALPHABETICAL INDEX.

The alphabetical system is the most simple and perhaps the most practical method for the average-size organization. The guides are made up in sets of 25, 40, 60, 80, 100, or more. The simplest division—that of 25—contemplates a card for each letter of the alphabet with the exception of the letter M, which has an additional card for Mc, and the letters X, Y, and Z are placed on one card. The other sets further subdivide the alphabet. Under each guide separate folders are provided for all regular customers or frequent correspondents, and the name of each is indicated on the tab. A folder is also provided under each guide for the miscellaneous correspondence to be filed under that subdivision. This folder is often of a different color so as to be more easily distinguished. The alphabetical method of filing is probably better than the numerical because it is simpler and no index of any kind is required beyond the divisional guides with which the file cabinet drawers are equipped.

THE NUMERICAL INDEX.

In numerical indexing a number is assigned to each person with whom considerable correspondence is carried on. The guides are usually numbered by tens and twenties, and between these the folders are placed in numerical sequence. To locate any particular folder an alphabetical cross index is necessary. This index consists of cards bearing the name and the folder number of each correspondent filed behind the proper alphabetical index so that it can be located easily. The alphabetical system provides a miscellaneous folder for all correspondents with whom only one or two letters are exchanged. The advantages to be derived from opening a separate folder for each of these correspondents would hardly warrant the expense. A folder is, therefore, sometimes used for miscellaneous correspondence, and all such miscellaneous correspondence is filed in this folder under one number. This is, however, hardly a satisfactory method, and it is often found necessary or advisable to use the numerical system for the heavy correspondence and an alphabetical index for the miscellaneous items. The numerical index admits of unlimited expansion

without interference with original or current files. Cross-indexing by subjects can also be done by using a system of cross-index cards.

FILING OF ACCOUNTING RECORDS.

As the business of most cooperative organizations is, in a way, not continuous, but goes by seasons, the usual procedure is to file all records at the end of the season. Too often no provision is made for storing these files in such a way that they are readily accessible for reference.

Matters of importance other than the regular financial transactions of the business should be carefully recorded so that they will not be overlooked. Papers pertaining to claims against railroads and express companies are often placed in the regular correspondence files and are lost sight of through a change in management or clerical force. Accounts which have proven uncollectible for the time being, and have been thrown into the "profit and loss" account, are also apt to be entirely forgotten when opportunities for collecting them are presented several seasons later. Such matters should be carried in auxiliary records in small bound books or card systems, so that instant reference is afforded.

SAFEGUARDING THE CASH.

When the amount of business done by an organization justifies the practice, all mail should be opened by some person other than the cashier, and a book or sheet should be provided on which the remittances received can be listed and totaled for comparison with the cashier's deposit slip. The letters and inclosures are then turned over to the cashier for entry on the cashbook. Entries should be very explicit, especially when the item goes to the credit of a general account, as in the case of remittances covering net proceeds of goods consigned. Here the car number and shipment number (if shipments are numbered), or name of consignee and date shipped, should be given, and account of sales and correspondence supporting this item should be filed with other papers of the shipment so that the same will be easily accessible for reference and verification.

Entries not relating to the receipt or payment of money should not be recorded in the cashbook, the journal being used for such entries. The cashbook totals should represent the true amount of money handled, as well as the correct balance.

Each day's full receipts of cash should be deposited in the bank as a total so that the debit side of the cashbook will exactly equal in amount the entries on the bank pass book. Since all receipts are deposited in the bank, it necessarily follows that a check must be drawn for each disbursement of cash. (For petty expenditures, see explanation of petty cash payments, p. 12.) All returned checks

should be retained and filed in numerical order so as to afford comparison with their corresponding entries in the cashbook or check register.

As checks are frequently lost, making it necessary to issue duplicates, it is well to protect the organization against loss, as there is the possibility of both original and duplicate checks being cashed. The payee, therefore, should be required to sign a bond of indemnity for twice the amount of the check.

At the end of each month a reconciliation should be made between the cashbook or check register and the bank pass-book balances. As, from the very nature of the business, many checks are liable to be outstanding at least at the end of months during which heavy payments are made, a permanent record of these reconciliations will be found of great assistance, not only to the auditor but to the book-keeper as well. This reconciliation can be made with very little additional work. When checks are returned from the bank they are sorted out numerically and checked off on the stub of the check book or check register, preferably with a small red-ink check mark. An adding-machine list is then made of all unchecked amounts, giving a list of outstanding checks. Notation is then made on cash book as follows:

Balance per pass book-----	\$2, 498. 30
Less O/S checks-----	1, 408. 00
Balance as shown on cashbook-----	1, 090. 30

All adjustments on account of collection charges or interest credits, etc., should also be shown. The numbers of the checks are then inserted opposite the respective amounts on the adding machine list, and this list is filed with the last check drawn for the month. When reconciliation is made for the following month, the returned checks are first checked against the outstanding list of the previous month, and all unchecked items on this list are then included in the new outstanding list. This obviates the necessity of turning back each time to find the unchecked items on the check book.

All checks and receipts, sales slips, vouchers, etc., should be numbered with a numbering machine. Any that are spoiled should be marked void and left in the book.

A regular system should be used for the acknowledgment of all cash sales or miscellaneous cash items received. A receipt book with carbon, all receipts being numbered in duplicate, has many advantages over the receipt book with stub. The carbon copy remaining for office files, being an exact duplicate of the original, allows no chance for error, as may occur in rewriting the amount on a receipt stub. By a system of numbering, all receipts can be accounted for.

PETTY CASH.

Should it be necessary to keep a small amount of cash on hand to cover petty cash disbursements, the Imprest System of handling these disbursements should be adopted.

A petty cash fund should be created to liquidate items not conveniently paid by check, by drawing a check for an even amount in favor of the petty cash fund or the cashier, sufficient to meet the requirements for petty cash expenditures for a certain period, say, one week. A receipt should be taken for each disbursement, and a record of these payments should be made on a specially ruled envelope or in a petty cashbook. At all times the cashier must have in the petty cash fund the difference between the original amount of the check and the total of the items disbursed, as shown by the receipts. From time to time, as the amount of cash becomes small, the receipts are totaled and presented to the proper official for approval. A check is then drawn for the total amount of these receipts, which are charged to the proper accounts. The petty cash fund is thus restored to its original size. The receipts are then initialed and placed in an envelope, which is filed away so that the receipts are accessible for auditing at the end of the year.

THE EXPENSE ACCOUNT.

Some organizations segregate their expense items under but two or three headings, using general expense as a miscellaneous account to which all expense items not coming under one of the few specific expense headings are charged; others go to the other extreme of opening many ledger accounts to make a segregation of the expense account, thus increasing the work in the ledger materially both in posting and in abstracting the trial balance. A better plan is to provide but one column for expense in each book of original entry, where needed, notation being made in the "Explanation" column indicating the segregation to be made. For the distribution of these items, a columnar book large enough to allow a column for each account is used, the headings being inserted for such segregations as desired, such as salaries, labor, inspector's expense, postage, advertising, telegrams and telephone, repairs, office supplies, and stationery.

It is not enough to show that certain disbursements were made on account of expense, but proper segregation should be made in order to show the expenditures for each class. This is especially true of subclassifications kept for statistical use, and comparisons of one year with another. These comparisons are useless unless all charges are entered under similar heads from year to year.

RESERVE FOR DEPRECIATION.

The generally accepted definition of a reserve is an amount set aside for a special purpose, such as a "reserve for depreciation." By depreciation is meant the ordinary wear and tear which occurs to assets used in any enterprise.

The true condition of an organization is not shown accurately upon the books unless provision is made for depreciation of assets. Regardless of repairs, ordinary wear and tear will occur and must be provided for by depreciation. The wear and tear of an asset is just as much a part of the cost of doing business as the cost of labor.

The extent of depreciation should be estimated as closely as possible and credited to a "reserve for depreciation" account at the time the books are closed for the year. This will decrease the net profit by the amount of depreciation, and set aside amounts to replace the assets out of the earnings. Supplies carried over are just as subject to depreciation as any fixed asset.

To provide properly for depreciation, "reserve for depreciation" account should be credited and "profit and loss" debited with the proper amount. The apportionment of this amount from one year to another should be on the same equitable basis. The simplest method of computing the annual rate at which depreciation may be charged off is on a fixed percentage of the original value, which would spread the depreciation equally over the life of the asset. A better method however, and one in which the apportionment of this amount from one year to another is made on a more equitable basis is by computing the depreciation on a basis of a fixed percentage on the diminishing value. This makes the charge heavier in the earlier years, the amount being reduced gradually from year to year. The cost of repairs is greater in later years, and by charging off a fixed percentage the cost of operating is equalized. This method also leaves a small residual value, since the entire cost can never be fully taken up, therefore this is the method generally adopted.

For example: Suppose an organization has machinery for which its books show it paid \$5,000. It is decided to carry 10 per cent of the remaining balance of this account to a "reserve for depreciation on machinery" account. The following entry is made in the journal:

Profit and loss	\$500
Reserve for depreciation on machinery.....	\$500

This transfers \$500 of the profits to be used in replacing the machinery.

On the balance sheet, however, "reserve for depreciation on machinery" should be deducted from the original cost of the machinery, instead of showing the machinery as an asset of \$5,000 and the depreciation as a liability of \$500.

This item therefore appears on the balance sheet as follows:

Machinery	\$5,000
Less reserve for depreciation of machinery.....	500
	4,500

The bookkeeper should, however, keep in mind in this connection the importance of distinguishing between repairs and improvements.

An *improvement* signifies that which adds value to the property. This addition may, but does not necessarily, increase the earning power of the property.

Repairs involve such expenditures as are necessary to keep the property to which they are applied in its original condition or appearance.

If any additions or improvements are made, they are chargeable to the asset account affected. For instance, if a machine costing \$1,000 is replaced by another costing \$1,500, the machinery account should be debited with the cost of the new machine and an entry should be made crediting "machinery" account and charging "reserve for depreciation" with cost of old machine.

Repairs are chargeable against earnings. Thus, the first painting of a building is considered cost, while a subsequent one is simply for the purpose of maintaining it, and is chargeable to repairs.

The following yearly rates of depreciation can be used in the above method of reducing the balance of the asset:

	Per cent.
Brick and reinforced buildings	2½
Frame buildings well constructed.....	5
Office equipment and fixtures	10
Engines	7 to 12
Boilers	10
Shaftings, pulleys, and hangings.....	5 to 8
Machinery	7 to 10
Tools.....	25

Tools should be limited on the books to half of their estimated life.

By making the proper charges each year for depreciation, as outlined above, the true value of the assets is not only shown, but provision is made for the replacement of these assets, which is essential in such organizations as creameries, cheese factories, canneries, cotton gins, packing houses, etc., where a considerable amount of the assets are subject to wear and tear.

DIVIDENDS.

The generally accepted definition of a dividend is a sum set aside by formal action of the board of directors out of profits available, to be divided among the stockholders and members. The method of distribution will depend of course entirely upon the plan of organi-

zation. Where the organization is formed as a stock company pure and simple, the dividend is apportioned to each stockholder on the basis of the amount of stock held by each. In strictly cooperative organizations a dividend is generally paid to stockholders at a rate to provide reasonable interest on the investment. The balance of the profits are prorated back to the members in proportion to the total amount of business done by each during the season. The amount paid as a fixed dividend on stock naturally will vary with the interest rates of different localities. In some cooperative organizations no dividend on stock is paid, but the entire profit is divided pro rata among the members, according to the amount of business done by each with the organization.

To be valid, dividends must be declared out of the organization profits—that is, out of the balance remaining after all current expenses of operating are paid, and fixed charges, which include amounts set aside as surplus and for depreciation, are provided for. Power to declare dividends is vested in the directors.

The real purpose of a cooperative organization for marketing farm products should be to obtain the highest possible price for products delivered to the organization, and to furnish supplies to members at a charge as near cost as possible, there being collected only a sufficient charge above the actual working cost to provide for an increase in working capital. If this is done, dividends to members will be cut to a minimum.

Some organizations return to the members the full amount received for the product, less actual expenses, withholding only a small amount for emergencies, this amount going into a fund to cover any possible losses during the year. The balance of this fund is rebated to the members at the end of the year, pro rata to the amount of business done.

The best plan is to allow invested capital a reasonable amount of interest, set up a surplus fund to increase the working capital if desired, but above these charges to return to the members, at the time statements are made, the total amount received for their product less actual expenses and the amount set aside for surplus.

TRIAL BALANCE BOOK.

In order to preserve the trial balance some bookkeepers prefer to open up a trial balance book. This book is ruled with a folio column, name column, and numerous money columns, usually 12, accommodating 6 trial balances on a double page. In this way it is necessary to write the headings of the accounts but twice a year.

The trial balance book can also be made in another form, with alternate long and short sheets, the long sheets extending beyond the margin of the short sheets the width of the name column. The

names of the accounts are written on this extension and as it overlaps the second sheet the accounts have to be written but once a year.

NECESSITY OF TAKING MONTHLY TRIAL BALANCE.

Many organizations, due to the rush of business during the heavy selling season, fail to take the necessary trial balances. This is a practice which should be discouraged, for it is of the utmost importance that a trial balance be taken, and it should not be set aside until it balances.

A discrepancy in the trial balance means one or more errors of unknown size. No office-manager can afford to allow errors of any kind to run on from month to month in the hope that they will be found during a lull in business operations. If there are errors in the books, they can not be depended upon to show the true condition of the business.

The greater the amount of business transacted, the more important the trial balance becomes. Errors should be hunted out immediately if they are known to exist, and there is no quicker way to find mathematical errors than through the trial balance.

SURPLUS.

Surplus indicates a portion of the profits withheld from distribution, or the accumulation by special assessments, for the purpose of establishing an addition to the working capital of the organization. It may be put to any use for which capital is needed.

Cooperative organizations should make arrangements to set aside specific amounts, or a percentage of profits, for the increase of working capital. As an organization grows, more capital is required to take care of the increase in business properly. The capital obtained at the outset in most cooperative organizations is barely enough to carry the business through from year to year. Frequently money is borrowed upon the security of directors to tide the organization over the busy periods when large amounts are required. The best way to put an organization on a sound financial basis is to secure a sufficient working capital to provide for ordinary working needs and thus free the organization from any necessity of managing on insufficient funds.

After the organization has once been established on a sound financial basis, loans, when needed, can be made on the credit of the organization without compelling the directors to become personally liable. It can be said that with but few exceptions cooperative organizations in this country do more business on less capital than any other class of business enterprises. This condition in many cases curtails the management to such an extent that it is impossible to secure the advantages for the members that could be obtained with

sufficient working capital. A very satisfactory way of accumulating a surplus is to levy a special charge per unit on the commodities delivered by the members, this amount to be set aside as an addition to the capital.

PREPARATION OF ANNUAL STATEMENTS.

The statements usually submitted by the treasurer to the members at the annual meetings are the balance sheet, the profit and loss statement, and the statement of expenses. These statements are for the purpose of showing the members the condition of the business at that time, the progress made during the year, and the expenses incurred. Therefore, they should be so prepared as to be readily comprehensible to the rank and file of the membership unaccustomed to reading such statements.

THE BALANCE SHEET.

The balance sheet (Form I) is a statement of the assets and liabilities of a business at a particular time. It is made up of the debit and credit balances remaining on the various accounts after the books have been "closed." Accountants do not agree as to the arrangement of the various items on the balance sheet, some starting with the most liquid and working toward the most fixed; others reversing this order. Either method is good, but it should be followed out on both sides so as to bring the most liquid assets opposite the most liquid liabilities and continuing in such a way as to bring the most fixed assets directly opposite the capital.¹

FORM I.—*The balance sheet.*

THE YORKVILLE PRODUCE EXCHANGE.

BALANCE SHEET AS OF DEC. 31, 1914.

ASSETS.		LIABILITIES.	
Cash on hand.....	\$30.00	Accounts payable.....	\$250.00
Cash in bank.....	1,360.00	Bills payable.....	2,000.00
	<u>\$1,390.00</u>	Capital and surplus:	
Bills receivable.....	540.00	Capital stock.....	8,190.00
Accounts receivable.....	2,000.00	Surplus—	
Less reserve for bad debts.....	60.00	Balance as of Dec. 31, 1913.....	\$300.00
	<u>1,940.00</u>	Net profit for year.....	540.00
Merchandise inventory as per schedule.....	3,000.00		<u>840.00</u>
Furniture and fixtures.....	\$800.00		
Less reserve for depreciation.....	40.00		
	<u>760.00</u>		
Buildings.....	3,000.00		
Less reserve for depreciation.....	150.00		
	<u>2,850.00</u>		
Land.....	1,000.00		
	<u>11,280.00</u>		<u>11,280.00</u>

¹ Another class of items which should appear on the balance sheet are "deferred charges," representing expenses paid but not chargeable against the period under consideration. As, for example, the stationery, office supplies, stamps, etc., on hand will be used during the next fiscal period and therefore are chargeable against the profits of that period. Other items such as "interest paid in advance," "insurance premiums prepaid," "rent paid in advance," etc., should all be taken into consideration.

THE PROFIT AND LOSS STATEMENT.

This statement presents in explanatory detail the gross profit made during the year and the expenses and losses incurred, it being a transcription of the "profit and loss" account on the ledger, and discloses the way in which the "net profit" or "net loss" appearing on the balance sheet is obtained. (Form II.)

FORM II.—*Profit and loss statement.*

Merchandise gross profit.....	\$2,255.00	
Commission.....	3,510.00	
Expense (per itemized statement).....	\$4,900.00	
Interest and discount.....	75.00	
Reserve for depreciation.....	190.00	
Reserve for bad debts.....	60.00	
Balance to surplus.....	540.00	
	5,765.00	5,765.00

THE EXPENSE STATEMENT.

The monthly totals appearing under the different headings in the expense book should be added and an itemized statement of expenses made. This will give in detail the expenses incurred during the year. (Form III.)

FORM III.—*Itemized statement of the expense account.*

Salaries.....	\$2,300.00
Labor.....	400.00
Traveling expenses.....	45.00
Taxes.....	29.00
Insurance.....	18.00
Office supplies and stationery.....	118.00
Advertising.....	260.00
Telegrams.....	460.00
Telephone.....	320.00
Postage.....	246.00
Light, heat, water, and ice.....	162.00
Painting and repairs.....	230.00
Garage.....	
Cartage.....	56.00
Directors' fees.....	110.00
Auditors' salaries.....	100.00
Rent.....	
Miscellaneous.....	46.00
Total.....	4,900.00

AUDITING.

The purposes of an audit are for protection against fraud, for the detection of errors and omissions, also to determine if the business is conducted along the most economical lines and in accordance with

statute and constitutional provisions of the organization, and for a certification to the correctness of assets, liabilities, and losses and gains as shown by the financial statement. Such an audit also helps in maintaining the highest financial standing, furnishing evidence of the organization's safety and prosperity. Auditing by a competent accountant not only tests the accuracy of the accounts but it secures an analysis of the business which promotes practical economy, in that the results of the year's business, as shown by the accounts, will display any weaknesses in the methods of operation and any needless or excessive expenditures. No one thing connected with the business of any corporate body is more important than the proper auditing of the accounts.

A great many cooperative organizations are inefficient in the matter of auditing, and every organization should provide for a system of internal audit, which can be carried on by a committee of the directors or members, and for an external audit, which should be made at least once a year, such external audit to be made by an expert accountant.

INTERNAL AUDIT.

For the internal audit it is usually customary for a committee of two, appointed by the board of directors from among themselves or the members, to come into the office each month and make as thorough an examination as possible of the receipts and expenditures, and note the general policy in carrying on the business. Such a committee audit brings the directors into closer touch with the policy of the management and has a tendency to make them feel a more direct responsibility. This examination will do much toward instilling confidence and keeping the business open to the members through the monthly reports of this committee.

For the internal audit, the larger organizations have an efficient office man who is regularly employed and who carries on a continuous internal audit. This is an excellent arrangement when the amount of business done by the organization warrants the expense.

EXTERNAL AUDIT.

The number of defalcations in business organizations occurring annually may be traced frequently to the fact that no audits by competent parties were made. The internal audit by a committee has many advantages, but is incomplete and not sufficient in itself as a protection against fraud nor for the proper analysis of the accounts. It is therefore necessary that an audit conducted by an expert public accountant be made at least once each year.

Many organizations have incorporated in their by-laws a clause requiring the employment of a public accountant to make a thor-

ough audit of the year's business before the annual meeting. Should the expense of a public accountant be prohibitive owing to the small amount of business transacted, a person who is thoroughly competent to carry on an audit should be employed, preferably some business man of high standing in the community who is not interested financially or otherwise in the organization.

AUDITING CIRCLES.

In the grain and dairying sections there are great numbers of cooperative elevators and cooperative creameries within a radius of a few miles. If each of these organizations were to employ an expert accountant to audit the books the cost would probably be excessive. Small associations or circles could be formed, however, by the cooperative organizations within a certain radius, who could enter into a contract with a competent auditor to do the auditing for all of the organizations. Such an arrangement would bring the services of an expert auditor to the organizations at a comparatively small cost.

CONCLUSION.

It is not unusual to read in a report concerning the failure or suspension of a business concern, that not until experts have been at work upon the accounting records for several days or weeks can the exact condition of the assets and liabilities be ascertained, or the amount of loss be discovered. The frequency with which this statement is made naturally suggests a connection between accounting and success. This connection will be found, on examination, to be existent in a large proportion of all business failures.

The accounting problems connected with the cooperative organizations in the United States generally do not receive the attention they deserve. The accounting system of any organization has a far-reaching effect upon the success or failure of the enterprise and upon the rights of the members interested therein. It is therefore necessary for the greatest success that the accounting system of any business enterprise be based upon the proper fundamental principles and conducted with the maximum degree of efficiency.

SUMMARY.

1. For the successful conduct of a cooperative business enterprise a complete business system is essential. Accounting records form a most important part of any business system.

2. A business system may be defined as a prearranged plan of operation governed by the general laws of business practice.

3. Bookkeeping may be defined as the systematic and chronological recording of financial transactions.

4. The double-entry method is the best for keeping any set of books, as it allows an equalization of debits and credits which affords a complete check on all entries.

5. The great number of books now used in recording financial transactions are forms of the journal and ledger, and the principles of double entry should apply to all books used for the recording of financial transactions.

6. It is of the utmost importance that a trial balance be taken each month. The trial balance is the best method of proving the mathematical accuracy of the books.

7. A convenient method of preserving the trial balance for future reference is that of using a trial-balance book.

8. Essential requirements for a system of accounting records for a cooperative marketing organization are—

(a) A complete set of financial records showing the business transactions and the results thereof.

(b) A record of each member's transactions with the organization.

(c) Capability of taking care of a maximum amount of business during the shipping season.

(d) Capability of returning to the members the proceeds from their products within a reasonable time.

(e) Clear pooling records when kept, so that any discrimination can be shown quickly.

(f) Auxiliary records which will give statistics and valuable information for the conduct of the business. These records must be accurate.

9. No two cooperative organizations are exactly alike. It is necessary, therefore, that a system of accounts, to be most successful, be devised to fit the business for which it is intended.

10. Care should be exercised in devising columnar forms, in order that columns which will be used rarely are not added, making the forms cumbersome. All statements showing returns or ledger accounts to growers should be so headed and constructed that they may be perfectly plain and intelligible at first glance.

11. There are numerous labor-saving devices for reducing the cost of accounting which may be used to great advantage by cooperative organizations.

12. Every cooperative organization should have an accountant who is thoroughly familiar with the business, in order that he may conduct the office properly.

13. Minutes in proper form of all stockholders' or members' and directors' meetings should be kept.

14. Notice of meetings should be regulated by the by-laws. Notice by publication and through the mail are the most common and best methods.

15. By-laws should contain measures of safety to regulate the handling of all organization funds.

16. Surety bond should be had for all employees handling funds.

17. A good system of filing for correspondence is essential for every office.

18. Proper filing of accounting records is necessary, in order that instant reference may be afforded and that valuable information regarding claims, accounts receivable, etc., may not be lost.

19. A regular system for safeguarding the cash should be adopted by all officers, and adhered to strictly.

(a) All entries of cash should be explicit, and items supporting such entries should be filed so that they are accessible for reference and verification.

(b) No entries should be recorded in the cashbook which do not relate to cash.

(c) The full receipts of each day should be deposited in the bank.

(d) All canceled checks should be filed in numerical order.

(e) Duplicate checks should always be covered by indemnity bonds.

(f) Reconciliation should be made each month between cash or check register and bank pass-book balances.

(g) Permanent record of these reconciliations should be made.

(h) Checks, sales slips, receipts, etc., should be numbered with a numbering machine. Any which are spoiled should be marked void and left in the book.

(i) A regular system should be used for the acknowledgment of all cash sales, or miscellaneous cash items received.

20. All petty cash payments should be made on the Imprest System.

21. A good plan for handling expense items is to carry a general expense account, making a segregation in a columnar book.

22. The wear and tear on an asset is a cost of doing business, and the true condition of a business is not shown accurately upon the books unless provision is made for depreciation in the value of the assets. The extent of depreciation should be estimated as closely as possible, and an amount to cover credited to a reserve for depreciation account at the end of the year. This allows for the replacement of the assets.

23. Cooperative organizations should make arrangements to set aside specific amounts, or a percentage of profits, for the increase of working capital.

24. Annual statements should be prepared in such form as to be readily comprehensible to all members. These statements should be

in such detail that all expenditures are itemized properly and profits shown in such a way that it is easy to determine just where they originated.

25. No one thing connected with the business of any cooperative body is more important than the proper auditing of accounts. Both an internal and external audit should be made at regular and frequent intervals. The internal audit is generally conducted by a committee of the members. The external audit should be made by an expert accountant and should be complete.

26. Auditing circles can be formed to great advantage when there are several cooperative organizations in the same territory.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 179

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

April 2, 1915

NATIVE AMERICAN SPECIES OF
PRUNUS

By

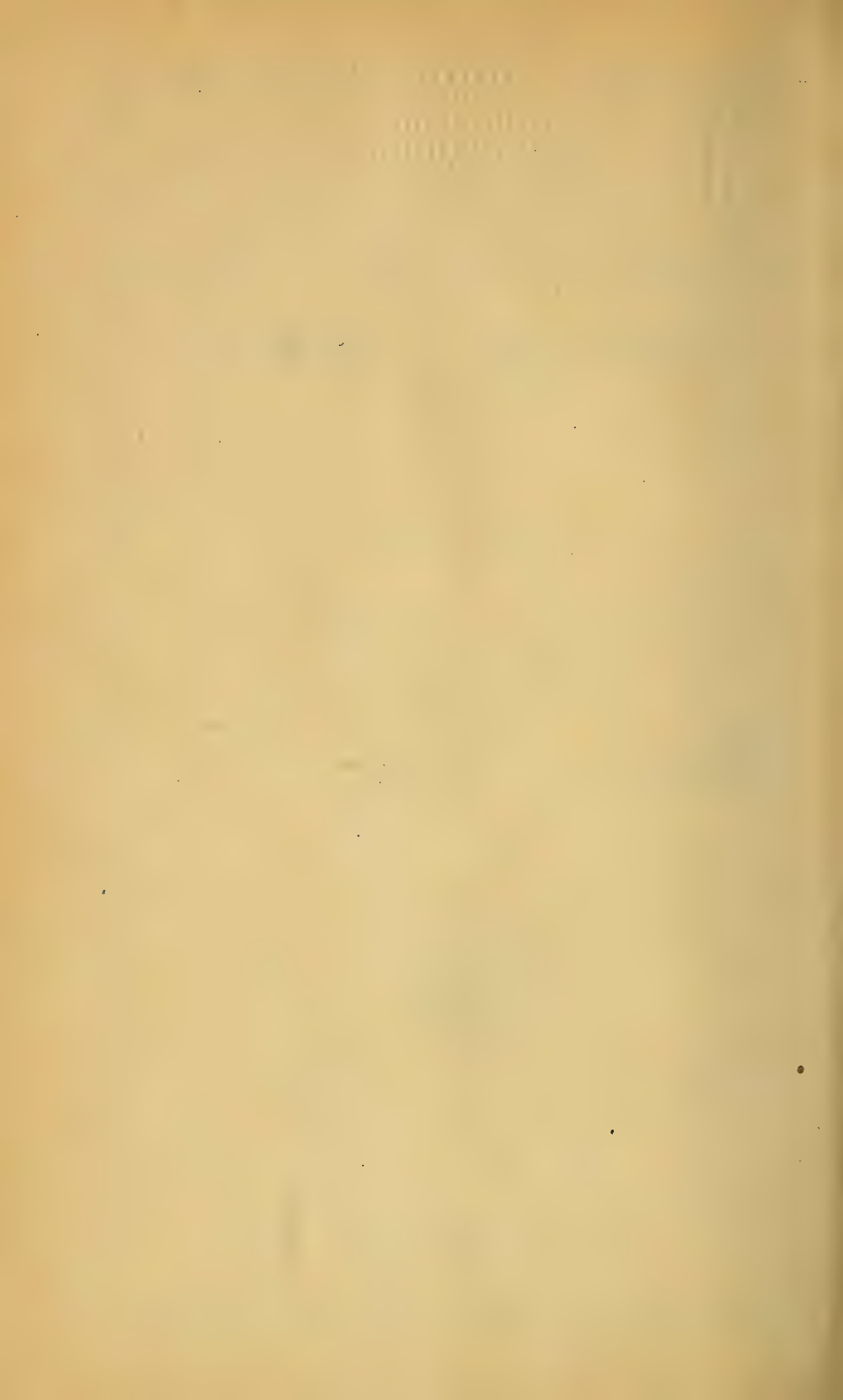
W. F. WIGHT, Botanist

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

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Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
April 2, 1915.

(PROFESSIONAL PAPER.)

NATIVE AMERICAN SPECIES OF PRUNUS.¹

By W. F. WIGHT,

Botanist, Horticultural and Pomological Investigations.

INTRODUCTION.

The present study embraces only those species of the genus *Prunus* which have an umbellate or corymbose inflorescence and which produce plumlike or cherrylike fruit, these being the ones principally of interest, either from the standpoint of their fruit production or their utilization as stocks in the propagation of other species. Indeed, the American species belonging to the subgenera *Padus*, *Laurocerasus*, and *Emplectocladus* seem sufficiently distinct to warrant the recognition of these groups as genera. If connecting species exist, they are to be found among the Asiatic representatives of the genus, and no satisfactory conclusions can be reached regarding generic limitations without a careful study of the species in the Old World.

DISTRIBUTION.

The genus *Prunus* is widely distributed in America, being represented in some portion of every State by one or more species. One species is found in northeastern Mexico, and one or more occur in nearly all of the southern provinces of Canada. Eight species are found within the limits of Texas, and it is probable that the greatest abundance of individuals is in the region comprising Missouri, eastern Kansas, Oklahoma, western Arkansas, northwestern Louisiana, and eastern and northern Texas. The species naturally grow mainly in open situations, some of them scarcely at all with other woody plants, and rarely under forest conditions. In some sections of the country the clearing of the forests and the use of such areas

¹ This manuscript was prepared in 1911 while the writer was associated with the Office of Taxonomic and Range Investigations.

NOTE.—This bulletin is intended for horticulturists in all parts of the United States, especially those who are studying varieties or doing work in plant breeding.

for pasture have afforded favorable conditions for a considerable increase in the number of individuals. In other localities the abandonment of cultivated fields has afforded very similar opportunities, with a like result. In still other regions, areas are being placed under cultivation, and by this or other means the number of individuals is being decreased. The horticultural literature of the Northwest contains so many references to the destruction of plum thickets that it is probable that in that region at least the genus is less abundant than when settlement began. The actual number of species may also soon be lessened, since a few of them are extremely local, and at least one of the latter, *Prunus alleghaniensis*, is known recently to have disappeared in some of the localities where it formerly existed.

VARIATION AND ADAPTABILITY.

There is great variation within the species in the size and quality of the fruit and apparently in the productiveness of individual trees. Any systematic attempt to improve the native plums should begin with a study of the species in the field in at least a portion of the range of each. In this way forms may be secured which so far surpass the usual quality of the species that they could otherwise be obtained only after many years of selection in the orchard. Several of the American species bear fruit that is distinctive in character and that possesses qualities of value. Their hardiness and adaptability to the regions in which they are native render some of them indispensable if those regions in which the Old World species are not successfully grown are to be supplied with home-grown fruit. Some of these may eventually be so improved that they will even find a place in localities where they will compete for dessert purposes with varieties originating from Old World species.

EARLY HISTORY OF AMERICAN PLUMS.

The history of American plums, so far as Europeans are concerned, probably begins with the visit of John de Verrazano, a Florentine voyager, who sailed from the vicinity of Madeira on January 17, 1524, under orders from the French king, Francis I. He reached America at about latitude 34° north, and proceeded northward along the coast to latitude 50°, when he departed for France. The explorer's account of his voyage is dated at Dieppe, July 8, 1524, and in his enumeration of American products observed at about 41° north, or the latitude of southern New York, he states (29, p. 362):¹ "We found Pomi appii, damson trees, and nut trees." The voyagers apparently nowhere went far inland, and the "damson trees" were with little doubt *Prunus maritima*, since this is the only species in

¹ Reference is made by number to "Literature cited," p. 73.

that region having foliage at all comparable with that of the damson plum. The fruit could not have been much more than formed at the time and, in fact, no mention is made of it.

A few years later, in 1534, Jacques Cartier (43, p. 17; 68, p. 31) observed some time during the month of July what was probably the fruit of *Prunus nigra*. "They have also plums, which they dry as we do for the winter; they call them Honesta." The fruit even of this species must have been brought some distance, for it is not known to occur far below the vicinity of Montreal, and no other in that region has fruit large enough to be dried in the manner described. On his second voyage (43, p. 35), plums were again observed by Cartier in the vicinity of an island which the explorers named Isle de Bacchus, and which is now known as the Isle of Orleans.

The account of Roberval's voyage (29, p. 294) in 1542 also mentions plums, as follows:

And in all these Countreys there are okes, and bortz, ashes, elmes, arables, trees of life, pines, prussetrees, ceders, great wall nut trees, and wilde nuts, hasel-trees, wilde peare trees, wilde grapes, and there have bene found redde plummes.

Another explorer, De Soto (16, p. 43, 61), landed in Florida on May 30, 1539, and the narrator relates that on October 27 they came to Anaica Apalache, which was probably not far from the present site of Tallahassee, Fla., and says:

There were other towns, where was great store of maiz, pompions, french beanes, and plummes of the countrie, which are better than those of Spaine, and they grow in the fields without planting. * * * There met him on the way [to Canasagua] twenty Indians, every one loaden with a basket ful of mulberries: for there be many, and those very good, from Cutifa-Chiqui thither, and so forward in other provinces, and also nuts and plummes. And the trees grow in the fields without planting or dressing them, and are as big and as rancke as though they grew in gardens digged and watered.

The first-mentioned trees, those seen in the autumn of 1539, may have been *Prunus americana*, since that species occurs in the locality specified, and in that section is the latest one to ripen its fruit. The second reference is perhaps to *P. angustifolia*, as the fruit ripens at the time mentioned, which was about the first of June, 1540. At Coça, or Coosa, about July 26, 1540, the author writes (16, p. 68):

There were in the fields many plum trees, as well as of such as grow in Spaine, as of the countrie * * *.

Cutifa-Chiqua appears to have been on the Savannah River below Augusta, Canasagua on the northern boundary of Georgia, and Coosa is supposed to be the locality now represented by Old Coosa on the Coosa River, in Georgia.

Plums are again mentioned as having been observed, probably in June, 1541, at the Indian town "Casqui" (16, p. 94). This locality was west of the Mississippi, but commentators differ as to its location.

Monette (56, p. 48) places it on the White River, about 150 miles above its junction with the Mississippi, McCulloh (48, p. 526), on the Red River beyond the "Wachita." It was evidently the custom of the Indians of the Southwest to dry fruit for use at other times than when it could be gathered fresh from the tree, for De Soto's narrator says (16, p. 119):

For when they came downe from Nicola, they saw on the other side of the river new cabins made. John Danusco went and brought the canoes loden with maiz, French beanes, prunes, and many loaves made of the substance of prunes.

This is supposed to relate to a locality on the Mississippi not far from the mouth of the Arkansas, and to have been in the latter part of April, 1542.

Plums are mentioned by René Laudonniere (29, p. 369) in "The Description of Florida," 1565; by William Strachey in Virginia, writing about 1610; by Francis Higginson, in "New England's Plantation," 1630; by William Wood, in "New England's Prospect," 1635; and by a number of others (5, p. 170-173).

A little less than a century after the above-named authors gave their accounts, John Lawson (41) gave a much better description of native fruits, as follows:

The wild Plums of America are of several sorts. Those which I can give account of from my own knowledge, I will, and leave the others till a farther discovery. The most frequent is that which we call the common Indian Plum, of which there are two sorts, if not more. One of them is ripe much sooner than the other, and differs in the bark; one of the barks being very scaly, like our American Birch. These trees, when in blossom, smell as sweet as any jessamine, and look as white as a sheet, being something prickly. You may make it grow to what shape you please; they are very ornamental about a house, and make a wonderful fine shew at a distance, in the spring, because of their white livery. Their fruit is red, and very palatable to the sick. They are of a quick growth, and will bear from the stone in five years, on their stock. The English, large black plum thrives well, as does the cherry being grafted thereon.

The American damsons are both black and white and about the bigness of an European damson. They grow anywhere if planted from the stone or slip; bear a white blossom, and are a good fruit. * * * I have planted several in my orchard, that came from the stone, which thrive well amongst the rest of my trees, but they never grow to the bigness of the other trees now spoken of. These are plentiful bearers.

There is a third sort of plum about the bigness of the damsons. The tree is taller, seldom exceeding ten inches in thickness. The plum seems to taste physically, yet I never found any operation it had, except to make their lips sore, that eat them. The wood is sometimes porous, but exceeds any box, for a beautiful yellow.

The native plums were observed by John Bartram (7, p. 19) on his journey from Pennsylvania to central New York in 1751.

Our way from hence lay through an old Indian field of excellent soil where there had been a town, the principal footsteps of which are peach trees, plumbs, and excellent grapes.

Plums were not infrequently found by early voyagers about Indian villages, and in some instances they may have been planted

and rudely cared for. The manuscript account by Conover (31, p. 58) of Sullivan's expedition indicates that when the village of Kanadasaga was destroyed, orchards of apples and plums were found crudely cultivated. William Bartram (8, p. 38) also refers to the cultivation of plums, although in a less convincing manner, as follows:

I observed, in the ancient cultivated fields, 1. diospyros, 2. gleditsia triacanthos, 3. prunus chicasaw, 4. callicarpa, 5. morus rubra, 6. juglans exaltata, 7. juglans nigra, which inform us, that these trees were cultivated by the ancients, on account of their fruit, as being wholesome and nourishing food.

These observations seem to have been made in the vicinity of Wrightsboro, eastern Georgia.

Again, in northwestern South Carolina, not far from Keowee (8, p. 331), "appeared the remains of a town of the ancients, as the tumuli, terraces, posts or pillars, old Peach and Plumb orchards, &c., sufficiently testify."

At the ancient town of Sticco (8, p. 343), Bartram again says, "here were also old peach and plum orchards; some of the trees appeared yet thriving and fruitful."

In all these instances in which plums are mentioned as being found in orchards, they were either with trees introduced by Europeans or were near settlements of Europeans. Earlier authors appear to have found groves of plums about Indian villages, but say nothing to indicate that the trees or seeds were intentionally planted or cared for, and perhaps this was not done until the coming of the white man. The Indian villages may have been established in proximity to plum groves, or these may have sprung from seed thrown away after the fruit had been brought for use from other localities.

EARLY BOTANICAL DESCRIPTIONS.

The first species to receive a botanical description was probably *Prunus americana*, for it is apparently this species which Plukenet (61, p. 306) describes as "*Prunus sylvestris Virginiana fructu luteo rubente rotundo, ossiculo lato & compresso*," and which he figures in his *Phytographia*, tome 216, as figure 7. The leaves are figured with acute serrations and are about the form of those of *Prunus americana*, while the description of the fruit and stone also accords well enough with this species.

In 1739, a little more than 40 years afterwards, two species were included in Clayton's *Flora Virginica* (28, p. 54), "*Prunus sylvestris humilior, fructu rubro praeeciori & minori, radice reptatrice*," and "*Prunus sylvestris, fructu majore rubente*." Although Linnæus is credited with the authorship of Clayton's *Flora*, these species are not included in the *Species Plantarum*. It is difficult to say whether Clayton's descriptions really represent more than one species or,

if only one, whether it is *Prunus angustifolia* or *P. americana*. Thomas Jefferson (34, p. 63) identified "*Prunus sylvestris fructu majori*" as the "Cherokee plumb," and "*Prunus sylvestris fructu minori*" as the "Wild plumb" (*Prunus americana*).

The next species to receive attention by a botanist was *Prunus pumila*, which had been introduced into the gardens of France and was described by Duhamel (19, p. 149) about 1755, as follows:

Cerasus pumila, *Canadensis oblongo angusto folio*, *fructu parvo*, *Cerisier nain à feuilles de Saule*. *Ragoumjer, ou Nega, ou Minel de Canada*.

Prunus pumila was the first to be given a binomial name, which distinction it received in 1767.

Humphrey Marshall (51, p. 110-114), who was the first author to treat any considerable number of species, described the following:

Prunus americana, "Large yellow sweet plumb"; *P. angustifolia*, "Chicasaw plumb"; *P. mississippi*, "Crimson plumb"; *P. maritima*, "Seaside plumb"; *P. declinata*, "Dwarf plumb"; and "*Prunus-Cerasus montana*, Mountain Bird-Cherry-Tree."

One of Marshall's species, *P. mississippi*, is not identifiable; the descriptions of the others are characteristic, however, and they are still recognized as distinct species, although some of them had been earlier described. A few of the species now known were unrecognized until recently, and perhaps others yet remain to be distinguished.

HORTICULTURAL HISTORY AND DEVELOPMENT.

Turning now to the recognition and development of native plums by pomologists, it is found that they were at first slow to recognize the value and distinctness of the American species, although in later years they have been almost the only ones who have studied the genus critically.

The earliest works devoted to fruits and fruit growing in America do not appear to make any reference to the native species, the first accessible reference being by Bernard M'Mahon (50, p. 588), who, in 1806, at the end of a list of plum varieties lists "*Chicasaw, Prunus chिकास*," but gives no description or note concerning the species. Another author, William Coxe (15, p. 232), writing in 1817, says that plums are—

Natives of the United States, in many parts of which they are found in great abundance, in numerous varieties of Colour, form and size, many of them in good flavour.

According to the same author, who lists 18 varieties, those cultivated in the gardens were either brought from Europe or produced from the stones of imported plums.

A few years later James Thacher (70, p. 223) says:

It is a fortunate circumstance that there are, according to Mr. Prince, of Long-Island, some kinds of plum not subject to the attack of the insect [the curculio] which are the

following: Chicasaw, Early Coral, Golden Drop, The Cherry plum, Flushing Gage, Yellow Egg plum, Balmer's Washington * * *.

The "Chicasaw" is the only one of these varieties that can be recognized as a native, and Thacher is perhaps the second author to refer in an American horticultural work specifically to a native, although the name "Chicasaw" may have appeared before in one of William Prince's catalogues, as well as in M'Mahon's work. Prince (63, p. 22), in 1828, mentions but does not describe the "Yellow and Red Chicasaw," and "American Red and Yellow," these being presumably *Prunus angustifolia* and *P. americana*. Three years later the same author (64, p. 104, 108) described "Red Chicasaw Pr. Cat. *Prunus chicasaw* Mich." as follows: .

This fruit is nearly round and of good size; the skin is of a fine cherry colour; the flesh yellowish, soft and melting when at full maturity, with a pleasant and peculiar flavor. This plum ripens from the 20th to the end of July. The tree is naturally low set and bushy, being inclined to spread its branches but a short distance from the ground. It also throws out short spurs, with leaves on them, each of which is terminated by a sharp-pointed thorn. Numerous suckers spring up from the root and serve as a means of propagation; but the trees which are inoculated on other stocks attain the handsomest form and make far the best appearance, and they have also the advantage of not generating suckers to the same extent. There is another variety which produces yellow fruit, but it differs only in respect to colour.

Prince also describes the Beach plum, and says:

The fruit is globular, often an inch in diameter, of a purple colour, with a glaucous bloom; it is pleasant for eating, and in flavour similar to the common plum.

This may seem rather extravagant praise of the Beach plum, yet there can be no doubt of the species, for he says:

Its natural location is near the salt water, along the coast and on islands. The fruit ripens in August and September. Gen. Dearborn, the enlightened and distinguished president of the Massachusetts Horticultural Society, has himself discovered several varieties of it growing in a wild state, two of which are purple, but vary in respect to size, and a third of a shining crimson colour; and it is to his liberality that I am indebted for the trees in my collection.

Prince does not describe *Prunus americana* in his Pomological Manual.

A native species is mentioned again in 1833 by William Kenrick (37, p. 256), a nurseryman at Newton, Mass., who includes presumably *Prunus nigra* under the name "Canada Plum." Kenrick says:

The tree is of medium vigor, diffuse in its growth; fruit small, oval, fiery red; flesh coarse grained and sour; juice abundant and aromatic. It is supposed to possess medicinal qualities.

This species is omitted by Kenrick in the edition of his work published in 1835, but it is referred to briefly by Fessenden (24, p. 246), who says:

A wild kind, found in the woods of Vermont, grows large and fair, but its fruit contains little saccharine matter. No doubt it might be improved by culture, and may furnish stocks for grafting.

Kenrick again refers to a native in 1841 (38, p. 230), when he describes the "Dwarf Texas Plum" as follows:

A low, dwarfish tree or shrub, rising 2 or 3 feet or more; the blossoms white, profuse, of a beautiful appearance, and in early spring resembling snow; the fruit of different colors, according to the variety, some being yellow, some red, and some purple; the flesh of delicious flavor; the produce most abundant. This new tree, or shrub, was lately introduced to our country from a small district in the colder part of Texas, and the upper Colorado, by my friend John B. Russell, Esq., of Cincinnati, Ohio. He is persuaded it must prove hardy.

This description suggests very strongly *Prunus angustifolia watsoni*, but possibly might also refer to *P. reverchonii*. It is almost certainly one or the other of these two. If it is really the sand plum, it is a little curious that it should apparently not again come to the attention of horticulturists until about 1890. It was, however, grown in gardens to some extent in Kansas and probably also in Nebraska, as early as 1880, or perhaps even earlier.

Thomas Bridgeman (11, p. 339) in 1840 and Michael Floyd (42, p. 303) in 1846 also mention native species and discuss them briefly, and an early edition of Thomas's American Fruit Culturist includes the "Red Chicasaw (*Prunus chicasa*)" (71, p. 347-348), which the author describes and says is "a native of the western states." Thomas is evidently more familiar with *P. americana*, concerning which he says:

There are many wild varieties of this species, the fruit varying from roundish to oval, and presenting various shades of color, mostly light red. Some have a pleasant, rich, sweet or subacid pulp. Tree 10 to 15 feet high, leaves ovate, coarsely serrate, branches somewhat thorny. Ripens latter part of summer. The quality of the fruit is improved by cultivation. It is sometimes used as stocks for the plum and apricot.

Thomas also describes the beach plum rather briefly and mentions these natives in some of the later editions of his work, but in that of 1867 all reference to them is omitted. Native plums were discussed by Elliott in 1854 (21, p. 402), who said *Prunus americana* was much used by nurserymen as a stock, seedlings of it often answering to work the same season. Elliott also throws some light on the attention that had been given at that time to the development of new varieties in general, in the following statement:

New varieties have thus far been produced from chance seedlings; no persons, to our knowledge, in this country, having exerted themselves to the production of varieties with any special view to the preservation of separate or combined characters.

Elliott lists the beach plum among his varieties, but says it should be discarded. This author in a later work (23, p. 95) discusses the native varieties a little more fully, and what he says concerning them indicates a more thorough knowledge of their merits and adaptability than is shown by almost any other author of a pomological work up to that time. Elliott's book is also one of the earliest general works to give a list of the native varieties known. The author says:

There are besides the cultivated varieties, known botanically as *Prunus domestica*, many others, native of our own country. They are known under various botanical terms, *Prunus Chicasa*, *Prunus Americana*, *Prunus Maratima* [*maritima*], and in general terms called *Chicasaw*, to the latter of which belong the varieties called *Wild Goose*, *Newman*, *Mountain Plum*, *Indian Chief*, one of the *Chicasa* family. The North and the South can depend for hardiness only upon what we call native varieties. Vermont can do little with our cultivated varieties, except in certain localities, and so with all the extreme North; while the records from South Carolina, Georgia, Tennessee, etc., give place only to our native wild varieties. Ohio and westward had originally many varieties of wild Plums, from round to oval, color from dark purple to red and yellow, time of maturity from September to midwinter, if the latter were not gathered. The trade in these native wild plums was at one time a large source of profit, but the clearing up of the country has destroyed them as it has blackberries.

Writing a little earlier than the publication of this later work of Elliott, D. W. Beadle (10, p. 118) evidently considers that there are possibilities in the species native to Canada, for he says:

Wild Plums are found growing in all parts of the Dominion, and may by judicious cross-fertilization become the foundation of a very hardy and valuable race of Plums.

Returning to an earlier work, one might expect in so comprehensive a publication as "The Fruits and Fruit Trees of America," by A. J. Downing (18, p. 263), to find the native species treated more fully than by most other authors. The whole discussion, however, is given in a footnote, in which the author says:

There are three species of wild plum indigenous to this country of tolerable flavor, but seldom cultivated in our gardens.

This is followed by descriptions of the three species *Prunus chicasa* [*angustifolia*], *P. americana*, and *P. maritima*. Downing refers the "Dwarf Texas Plum" of Kenrick to *P. angustifolia*. The edition of this work issued in 1890 still contains the statement originally made concerning the native species.

Barry (6, p. 120-121), in 1852, treats of the American species in the following brief manner:

The *Canada* or *Wild Plum*, which abounds in Ohio, Michigan, and other Western States, are distinct species, and reproduce themselves from seed. The seedlings of some grow extremely rapid, making fine stocks in one year on any good soil, * * * and we have no doubt some native species, as for instance the *Beach* and *Chicasaw* plums, small trees, will make good dwarf stocks. I am inclined to think, however, that very nice garden trees may be raised on the smaller species of the *Canada* plum. The first year's growth and even the second are quite vigorous on them, but after that the vigor diminishes, and the trees become quite prolific. This and the cherry plum will probably become our principal stocks for dwarfing.

Perhaps the earliest pomological work in which varieties originating from native species are described is that of S. W. Peek (60, p. 186), published in 1885. The author of this work was the proprietor of the Hartwell Nurseries, at Hartwell, Ga., and doubtless his southern location accounts for his interest in these varieties, which are, with two exceptions, of southern origin. The varieties described are the

Bassett, Cumberland, Marianna, Miner, Newman, Weaver, and Wild Goose.

Only a few years later Eliphas Cope (14, p. 8) published at New Lisbon, now simply Lisbon, in eastern Ohio, a pamphlet of 45 pages devoted entirely to plums, but here again the native varieties are dismissed with a single paragraph:

The native plums should not be planted but sparingly, only when they have been tried and given satisfaction. North of 40° latitude we question if they will give satisfaction or remuneration for labor.

The author of this statement must have been quite unfamiliar with the development and utilization of the native species taking place at that time in the States of Illinois, Wisconsin, Iowa, and Minnesota, where they were rapidly becoming of great importance.

The brief discussions of the native species by the authors quoted above show that after two centuries of occupation by Europeans the native species held a relatively very unimportant place in American pomology. In 1850, a few years earlier and later, respectively, than the publications of Barry and Downing, the center of population in the United States was near Parkersburg, W. Va. The people of the Southern States were little engaged in fruit raising, and the industry was therefore mainly confined to the States east of the Great Lakes and north of the Ohio and Potomac Rivers, a region in the greater part of which the varieties of *domestica* and *insititia* origin are grown with success. As the population of the country increased and spread westward beyond the region in which European varieties of plums were successfully grown, attention began to be directed more and more toward the utilization of native species, and this interest was accelerated by reason of the ravages of the curculio and the belief of many people that native plums were less affected by the insect.

The first efforts at plum culture, however, even in the States of Illinois, Wisconsin, and Iowa were mainly with those varieties of the Old World species that had been known in the Eastern States. Failing with these, the attention of fruit growers was of necessity turned to the native varieties, and a few were quite optimistic as to the outcome. Among these was J. S. Stickney (69), of Wauwatosa, Wis., who, in an address before the Iowa Horticultural Society in 1877, said:

I am dreaming that among these [native plums] there is something valuable; their endurance, productiveness, and perfect hardiness should and *must* be made useful to us, and we have no right to rest or flag in our efforts until we have an orchard of native plums that shall command in market two to four dollars per bushel, and yield crops as abundant and frequent as the wild ones in our thickets now do. About the possibility of this there is very little doubt * * *.

A little later D. B. Wier, a prominent horticulturist at Lacon, Ill., grew all the native varieties he could secure, while in Iowa, J. L. Budd, Capt. Watrous, and others very early recognized the value of

the native plums and contributed in a marked degree to their introduction and development. At this time, however, the native species were poorly understood, some of them were undescribed, and information concerning their hardiness and adaptability to certain regions could be had only by growing them. Although the need of some scientific basis for the classification of varieties was recognized, it was not until 1892 that anything of the kind was seriously attempted, and perhaps no other single event so stimulated and influenced the culture of the varieties of the native species as the publication by L. H. Bailey (2) of "The Cultivated Native Plums and Cherries," which was the first real scientific work on these fruits to appear in many years. Horticulturists in other agricultural experiment stations, following the passage of the Hatch Act, also became active in testing and to some extent in breeding varieties, so that in the years from 1888 to 1900 there appeared more than 70 bulletins devoted wholly or in part to this subject.

Having followed the development and utilization of the native species throughout the greater part of the last century, as shown in the general works on the culture of fruit in America, it is of interest to turn to the development of horticultural varieties from these species. The history of this development is to be found mainly in the proceedings of horticultural societies, in horticultural and agricultural journals and papers, and sometimes even in nursery catalogues. Many able and enthusiastic horticulturists have been concerned in this development, and among those who took a prominent part in this important work in Minnesota were O. M. Lord, J. S. Harris, H. Knudson, Peter Gideon, Martin Penning, Charles Luedloff, and C. W. H. Heideman. In Iowa, H. A. Terry began to grow the native plums more than 40 years ago, and he has originated more varieties than any other individual. Edson Gaylord and, more recently, N. K. Fluke have been prominent in the introduction of varieties, while C. G. Patten has originated a few and tested many more. Theodore Williams was for many years active in Nebraska, and N. E. Hansen is at the present time doing an important work in South Dakota.

While this work in amelioration was going on in the West, J. W. Kerr, on the Eastern Shore of Maryland, had been making a specialty of native plums since 1872, and had found among them the most profitable varieties he could grow. Farther south, J. S. Breece, of North Carolina, within the last few years has introduced a number of varieties, these being mainly hybrids with the Japanese plums. Horticulturists in Texas also early began to turn their attention to the native species, and Gilbert Onderdonk, T. V. Munson, and A. M. Ramsey have each introduced a number of varieties, while

more recently F. T. Ramsey, A. L. Bruce, and D. H. Watson have originated a number.

Many other growers have cultivated and originated new varieties, but the names here mentioned will serve to indicate where the greatest activity has been and what influences have aided this development. The contribution that each of these men has made toward the utilization of the native species is not, however, to be measured merely by the number of varieties that have been introduced, for an equal or sometimes greater service has been rendered by growing the untried varieties and freely making known the results of this experience before horticultural societies and elsewhere.

It would probably be very difficult to tell when the first recognized horticultural variety of native origin received a name, but excluding such terms as "Red and Yellow Chickasaw," "Red and Yellow American," and "Beach Plum," which are group names and can scarcely be considered as horticultural varieties in the same sense as the Weaver, De Soto, Miner, and Wild Goose, the first variety to receive this distinction was apparently the Miner. This variety was first known by other names, and the use of the name Miner may have been no earlier than the application of other names to other varieties of about the same period. This event is of so much importance in the development of American plum varieties that it deserves as complete a history as may be given, and of the several accounts, differing in details and even sometimes in essential facts, the following one by Mr. Giddings (26, p. 332) is generally credited as being authentic:

The Miner plum.—I have been kindly asked by a number of members of this society to write the history of the Miner plum. There is no fruit that has been talked of more of late at the West and of which so little is really known as the Miner or Hinckley plum. Its origin having become a mooted question, I will endeavor to give you a true history. I know that Charles Downing gave credit to Mr. Miner for originating it; but let us give credit to whom credit is due. This plum has been traced into Mr. Hinckley's hands several times by different parties, but no further. It is thought he bought it of a tree peddler, and perhaps he did, but I am now inclined to think he *did not*. At any rate, if Mr. Hinckley bought it of a peddler, he was not the first man who brought it to Galena. Though not known to have been cultivated in any nursery, it is now known to have been disseminated by sprouts among the farmers for more than 50 years in the State of Illinois; and Mr. Hinckley's peddler could easily have picked it up at some farmer's house. We here give the true history: In 1813 one Wm. Dodd, then an officer under Gen. Jackson, found this plum growing among the Chickasaw Indians at the horseshoe bend on the Talaposa creek. His attention was called to it by the beauty, size, and excellence of quality of the fruit. In the year 1814 he brought the seeds of this plum with other valuable fruits collected by a friendly Chickasaw Indian chief to Knox county, Tenn. Here he planted his seed and raised the first trees. In Knox county, Tenn., they went by the names of "Old Hickory" and Gen. Jackson. About the year 1823 or 1824 Wm. Dodd moved to Illinois and settled near Springfield. He brought with him some sprouts

of "Old Hickory" plums. He planted these in some newly broken sod, and they did not do so well. Having left a brother in Knox county, Tenn., to come to Illinois the next spring, he wrote to him to bring more sprouts of the noted "Old Hickory." His brother left Tennessee the spring of 1824-5, and instead of going to Sangamon county he went to Galena, taking with him a bundle of the plum sprouts intended for his brother. Finding himself so far from his brother, the sprouts were given away or sold, and for aught I know Mr. Hinckley may have received some or all of them. Anyhow it can be abundantly proved this is how this now noted plum first came to Galena.

Some of Wm. Dodd's trees in Sangamon county finally got to growing, fruiting, and sprouting, and they were distributed to some extent among his neighbors, but not, so far as known, among nurserymen. In Sangamon county the plum was called "Wm. Dodd" and "Chickasaw Chief." Some time after moving to Illinois Mr. Dodd, hearing of some very fine plums near Galena, sent for some cions, and behold he got the identical Wm. Dodd plum. Upon putting this and that together, of course Mr. Dodd felt satisfied that the famous plums at Galena had sprung from the sprouts taken there by his brother in 1824 or 1825.

In those early days no one disputed the fact that Mr. Dodd really brought this plum from Tennessee. If any more special proofs are wanted for the facts (for facts they are) we have given, it can be gained by applying to Wm. Dodd's grandson, living at Flint, Mahaska county, Iowa, or his mother's sister—now over 70 years of age—near Springfield, Ill.

Another account by H. H. McAfee (44, 45, 46), a resident of Freeport, Ill., and later of the University Farm, Madison, Wis., differs somewhat from that given by Mr. Giddings. Mr. McAfee says the plum was known under various names, "Miner, Townsend, Isbell, Peach, Chickasaw, etc.," and relates its history as follows:

In 1832, a man named Knight brought from southern Ohio, by boat to Galena, a stock of small trees, which he disposed of to the late Major Hinckley and others. The trees planted by Major Hinckley are still in full vigor, and bearing, and may be seen at his old place near Galena. The year following the first importation, Knight brought a second lot of trees, and planted most of them on Mr. George Townsend's farm, in the eastern part of Joe Daviess county. From these stocks the most if not all of the trees disseminated under the various names mentioned above have sprung; and as Major Hinckley was largely instrumental in securing the general planting of the plum, generously giving them away to his neighbors and friends, and as he grew them first in the west, it was decided by that society [Northern Illinois Horticultural Society] that the name "Hinckley" could with more propriety than any other be applied to all these plums springing from Knight's importation, except the seedlings. The name "Miner," applied by Mr. Barber at a late date in honor of the man from whom he derived his trees, is not defensible on any rules of pomological nomenclature; and the other names mentioned above are in a like manner objectionable.

It appears from a later account (47) that trees were disseminated by Maj. Hinckley, and the variety came into the possession of a Mr. Townsend, who grew the trees in a nursery for sale. From this circumstance the variety was often known as the "Townsend." A relative of Mr. Townsend took some of these trees to Lancaster, Wis., and from this stock trees were grown by Joel Barber, who gave

them the name of Miner, in honor of his father-in-law, Mr. Miner. D. L. Adair (1, p. 145), of Hawesville, Ky., says:

This plum received its name from a Mr. Miner of Grant County, Wis., who took the trees there from Illinois.

Whether Maj. Hinckley really obtained his trees from the brother of William Dodd, who went to Galena, or from Mr. Knight, can scarcely be determined with certainty from the conflicting statements that have been published. Possibly both accounts are substantially correct and the variety was taken into Illinois, first from Tennessee and a few years later from Ohio. Both accounts agree as to the possession of the trees by Maj. Hinckley. There can also be little doubt of how the name Miner came to be applied, and as early as 1869 the variety was widely known by that name.

The first mention of the name Miner in a publication is apparently in the April number of the *American Agriculturist*, in 1867 (54), where information concerning it is requested. This notice brought a reply printed in the July number from N. C. Goldsmith, Middletown, N. Y., which would indicate that the variety was quite widely disseminated under the name Miner even at that time. A year later, in the February number of the same paper, "W. W." (73), Grant County, Wis., says:

I have raised the Miner plum for five or six years; I got it from Mr. Miner, in Grant Co., Wis., who bought his trees of a man in Illinois, who did not have any name for them, so they were called the Miner plum. The true name is Chickasaw plum. A Mr. Isabell, of Joe Davis Co., Ill., has raised the same plum for more than twenty years.

Grant County is in the extreme southwestern part of Wisconsin and joins on the north Jo Daviess, the county in which Galena is situated, where the Miner was supposed to have been taken in 1824 or 1825. The reference by Downing to Mr. Miner, of Lancaster, Pa., is undoubtedly an error for Lancaster, Wis.

This Mr. Miner seems to have desired to assume the credit for having originated the variety, according to the account written by Joseph L. Budd (12), who says:

A certain Mr. Miner brought this plum to Lancaster, Wisconsin, some sixteen years since, with the statement that it was produced from pits planted by him of the Yellow Egg or Magnum Bonum Plum [a variety of European origin] a number of years previous, and that it had been disseminated alone from the sprouts taken from the original seedling tree as planted by him.

The variety is figured and described in the November number of the *Horticulturist* (55), in 1867, but it is preceded in point of description by the Newman variety, described but not figured in the September number of the same journal (22). This note in the September number, from Mr. Elliott, of Cleveland, Ohio, is of interest in connec-

tion with the natural distribution of *Prunus munsoniana*, to which the Newman belongs. Mr. Elliott says:

In my earlier days I frequently met with wild plums in Ohio and have often done so in Missouri, that were almost if not quite identical, and in the years 1836 to 1845, or thereabouts, they were abundant in the markets of all the western towns and cities.

The variety Newman is again described and figured by D. L. Adair (1, p. 142), from whom Mr. Elliott received his specimens, but the origin of the variety is not given. Mr. Adair was evidently somewhat of an enthusiast in the development of native fruits and apparently enumerated all of the varieties of native plums known to him. These were the Newman, Langsdon, Miner, Muldraughs Hill, and Wild Goose. The Langsdon, as described and figured, appears to be *Prunus hortulana*. The Muldraughs Hill is said to have been found wild on Muldraughs Hill, Hardin County, Ky., and is evidently *P. americana*, probably being the first-named variety belonging to that species. It has apparently not been grown to any extent, at least not under that name. The Wild Goose, the first representative of the second species to become prominent horticulturally, is perhaps the most widely disseminated and best known of any variety of the native species. The history of its origin is given by Miller (52; 53), as follows:

This invaluable fruit was first made known to the public about twenty years ago by Capt. Means, of Middle Tennessee, who, having killed a wild goose, discovered a plum seed in it, which he planted, out of curiosity. It grew rapidly, and fruited the third year; and being convinced of its superior qualities, he made it known to various nurserymen, who, from this same, propagated all the genuine Wild Goose plums that are now so deservedly popular wherever known. This plum is undoubtedly a seedling of the Chickasaw, but so much superior to it in size, quality, firmness, adaptability to shipping long distances, and its immense productiveness, as well as its early bearing, rapid growth and long duration, as to fully entitle it to a distinct appellation.

In the later account this writer says that the gentleman who first made it known lived in the vicinity of Nashville, and that until within a few years it had been controlled by a few propagators, but that it was then becoming known generally throughout the Mississippi Valley and in some of the Western States. An orchard of this variety in southwestern Tennessee was then 15 years old.

The history of the origin of the Wild Goose plum is also given by J. S. Downer (17, p. 116) and by L. H. Bailey (5, p. 176), who gives substantially the same account as that given by Mr. Downer. There was evidently, as in the case of the Miner, a disposition to give the credit of the discovery of this variety to more than one individual, for in the American Horticultural Annual of 1870 (62), among the varieties of the previous year, the following statement is made:

Specimens of the Wild Goose plum were sent us by Mr. Samuel A. Barber, of Madison, Tenn., who claims that the original tree "was raised by M. E. McCance, my father-in-law, from seed taken from a wild goose's craw."

Mr. Barber does not state where his father-in-law lived, while Mr. Downer's account places the original tree in the neighborhood of Columbia, Tenn., and states that at about 1850, the time when James Harvey, of Columbia, gave him an account of the origin of the plum, there were no conflicting statements in regard to it. The attempt was made to propagate this plum from seed as well as by budding, and this resulted in considerable diversity in the variety grown as Wild Goose and differences of opinion concerning it. Some of these seedlings received local names, as the Nolan, Hog, Goose Egg, Tennessee, and King of Plums. The Wild Goose was introduced into Iowa before 1871 by H. A. Terry, who obtained it from W. S. Rainey, of Columbia, Tenn. It was also offered in 1871 by William Parry, of Cinnaminson, N. J., and this date evidently marks the beginning of its wide dissemination.

Another event of particular importance in the development of fruits for the northern Mississippi Valley and the eastern Plains region was the introduction of the De Soto plum, this being apparently the first variety of *Prunus americana* to be extensively propagated and to attract attention to the horticultural development of this species. The history of this variety is given by C. G. Patten (59, p. 237), of Charles City, Iowa. The first settler on the land where this plum was found at De Soto, Wis., was an American by the name of Tupper, who located there in 1853 or 1854. The original settler sold the farm in 1855 to the Trayer brothers, who were Frenchmen. There were at this time three or four groves of wild plums on the farm, and these the new owners destroyed, with the exception of the one later known as Trayer De Soto and De Soto, which produced such superior fruit that it was preserved. The next possessor of the farm was a Mr. Steven Heal. At some time a small orchard must have been planted on the place with trees from this original wild grove, for such an orchard was described as consisting in 1881 of 60 trees, the largest having a trunk diameter of about 10 inches. The variety began to be propagated and disseminated about 1864 by a Mr. Hale, who lived at Lansing, Iowa, only a few miles from De Soto.

The Bixby (72, p. 434), another *americana* plum, may be even older than the De Soto, but it seems to have been less widely grown. This variety was named for "Father Bixby," who settled in Clayton County, Iowa, in 1847, and on whose place the plum was then growing. Forty years later the trees were still thriving. These varieties were the beginning, the first developments, in a species that before the close of the century was to furnish more varieties than any other native.

While the first name for a native plum that may be termed varietal in the pomological sense seems to have been published in 1867, there have now been applied, either to varieties of the native species or to

their hybrids, more than 800 names, a development that has taken place in less than 50 years. During the decade from 1890 to 1900 the increase in the number of varieties was exceptionally marked. Many of these differ very little from each other and often are little or no better, doubtless in some cases not so good, as those which may still be found in a wild state. During the last decade there has been perhaps less interest, and probably only about 70 varieties of natives or their hybrids were offered by the nursery trade in 1911. Too many varieties have been produced without sufficient knowledge of the distinguishing characters of the species or of their relationships, and a reaction has inevitably followed the feverish dissemination of new varieties. In the beginning of horticultural development this is perhaps unavoidable. Much pioneer work has to be done before a basis for scientific development can be obtained, and now, after 50 years of work, the real substantial improvement remains to be accomplished.

SYSTEMATIC BOTANY.

The botanical treatment given the species in the following pages may perhaps be considered a broad one. There will always be differences of opinion as to what constitutes a species, and the study of a small amount of material which did not show the gradual variation from the aspect assumed by a species in one part of its range to that assumed in another part might have led to different conclusions. Fortunately, a large amount of material has been available. Further study of the species in the field will continue to afford interesting results concerning their variations and relationships, particularly in the Southern and Southwestern States. Many of the species extend over a considerable range of territory. Most of them are variable, but these variations have been very carefully considered, and it is believed that to have established species on the slight differences that have sometimes served as the basis for proposed species when a small amount of material was available would mean the description of hundreds of forms—they can not be termed species—and there would still remain hundreds of others intermediate in character.

The present treatment has been based on a study of nearly all the species in the field, of more than 400 horticultural varieties, and of the collections of the Bureau of Plant Industry, the United States National Herbarium, the Arnold Arboretum, the Gray Herbarium of Harvard University, the New York Botanical Garden, the Missouri Botanical Garden, the Herbarium of the Geological and Natural History Survey of Canada, the New York State (Geneva) Agricultural Experiment Station, Cornell University Agricultural Experiment Sta-

tion, the Academy of Natural Sciences of Philadelphia, the Milwaukee Public Museum, the University of Wisconsin, the University of Minnesota, the Kansas Agricultural College, the Michigan Agricultural College, the Northwestern University, the Chicago Academy of Sciences, the Leland Stanford Jr. University, the University of California, and the Field Museum.

SYNOPSIS OF THE SPECIES.

PLUMS.	PLUMS—continued.
Americana group:	Maritima group—Continued.
<i>Prunus nigra</i> .	<i>Prunus umbellata</i> .
<i>americana</i> .	<i>umbellata injucunda</i> .
<i>mexicana</i> .	<i>umbellata tarda</i> .
Subcordata group:	<i>gravesii</i> .
<i>Prunus subcordata</i> .	<i>maritima</i> .
<i>subcordata oregana</i> .	Gracilis group:
Hortulana group:	<i>Prunus gracilis</i> .
<i>Prunus hortulana</i> .	<i>venulosa</i> .
<i>hortulana mineri</i> .	
<i>reverchonii</i> .	CHERRIES.
<i>rivularis</i> .	
Angustifolia group:	<i>Prunus pennsylvanica</i> .
<i>Prunus munsoniana</i> .	<i>pennsylvanica corymbulosa</i> .
<i>orthosepala</i> .	<i>emarginata</i> .
<i>angustifolia</i> .	<i>emarginata villosa</i> .
<i>angustifolia watsoni</i> .	
<i>angustifolia varians</i> .	DWARF CHERRIES.
Maritima group:	
<i>Prunus alleghaniensis</i> .	<i>Prunus pumila</i> .
<i>alleghaniensis davisii</i> .	<i>cuneata</i> .
	<i>besseyi</i> .

KEY TO THE SPECIES.¹

1. Leaves various in form, the serrations extending practically to the base, somewhat pale below or green on both surfaces. *Flowers with the calyx more or less pubescent, except in Prunus nigra (northern species with large flowers and reddish calyx) and in species with more or less corymbose inflorescence* 2.
1. Leaves obovate-spatulate or sometimes lance-oval on succulent shoots, entire toward the base and pale below with a glaucouslike color. *Flowers in umbellike clusters, the calyx lobes small, obtuse, and glabrous* 19.
2. Leaves usually with at least the petiole finely pubescent along the upper edge or a few scattered hairs along the midrib below or with small tufts in the axils of the lateral veins. *Inflorescence umbellike; fruit 12 to 35 mm. in diameter, usually with more or less bloom, flesh edible* 3.
2. Leaves glabrous even to the petiole, or pubescent in some forms, but not more so along the midrib than elsewhere and not tufted in the axils. *Inflorescence more or less corymbose; fruit 6 to 10 mm. in diameter, without any trace of bloom, flesh thin and sour* 18.

¹ Since flowers appear before mature foliage, that part of the key referring to the inflorescence has been italicised to facilitate its use with the character of material to be identified.

3. Serrations of the leaves rounded or obtuse (sometimes apparently acute by the presence of a pointed gland, rarely acute in *P. subcordata* Pacific coast species with incisely serrate leaves, and in *P. orthosepala* with glabrous leaves), mostly glandular, at least when they first unfold. *Flowers with glandular calyx lobes, except in P. orthosepala and P. angustifolia, species in which the calyx lobes are merely ciliate, and in P. venulosa with flowers only 6 to 7 mm. broad* 4.
3. Serrations of the leaves pointed or acute, the teeth mostly not gland tipped when the leaves unfold. *Flowers with calyx lobes eglandular except sometimes inconspicuously glandular in P. americana* 5.
4. Leaves broadly oblong-ovate to slightly obovate, not at all trough shaped, the margin often doubly serrate. *Flowers 2 to 2.5 cm. broad, the calyx usually with a reddish tinge, at least in age, the lobes lanceolate, conspicuously glandular-serrate* *P. nigra.*
4. Leaves ovate, ovate-lanceolate, oblong-lanceolate or sometimes oblong-oval (often orbicular in *P. subcordata*, Pacific coast species) the margin rarely doubly serrate. *Flowers 8 to 15 mm. broad, with calyx rarely or only slightly reddish, the lobes oblong-ovate, entire, glandular or eglandular* 7.
5. Leaves rather abruptly acuminate, the margins rather coarsely and deeply serrate. *Flowers 18 to 25 mm. broad. Fruit red or reddish yellow, 18 to 30 mm. in diameter* 6.
5. Leaves gradually acuminate or merely acute, the margins rather finely serrate. *Flowers 6 to 14 mm. broad. Fruit purple or more rarely red or yellow, about 15 mm. or less in diameter*.. 14.
6. Tree sprouting from the roots and forming thickets, bark scaly on older trunks; leaves glabrous or sparingly pubescent or in the subspecies tomentose below, acuminate even when they first unfold. Fruit ripening from August to October or in the South in July, stone oval. *P. americana.*
6. Tree not sprouting from the roots and not forming thickets, bark somewhat furrowed on older trunks; leaves usually strongly tomentose below, commonly somewhat obtuse when they first unfold. Fruit ripening in October and November, rarely in September, stone obovoid to nearly round *P. mexicana.*
7. Leaves orbicular to oval or rarely ovate, mostly obtuse at the apex, the margins incisely serrate, sometimes doubly so. *Flowers 15 to 18 mm. broad* *P. subcordata.*
7. Leaves ovate, ovate-lanceolate to oval, mostly acute at the apex, the margins crenate or crenulate, or at least not incisely serrate. *Flowers 8 to 15 mm. broad*..... 8.
8. Leaves rather thick, ovate or ovate-lanceolate, only slightly lustrous on the upper surface, veins usually conspicuous below, the margin rather coarsely and irregularly serrate..... 9.
8. Leaves usually rather thin, oblong-lanceolate to oval, lustrous on the upper surface, veins not very conspicuous, the margin finely and evenly serrate..... 12.
9. Tree not sprouting from the roots and not forming thickets; leaves 7.5 to 11 cm. long. *Flowers 12 to 15 mm. broad*..... *P. hortulana.*
9. Shrubs sprouting from the roots and forming thickets; leaves mostly 5 to 7.5 cm. long. *Flowers 9 to 10 mm. broad*..... 10.

10. Young branches glabrous; pubescence of the leaves usually more abundant along the midrib and more or less tufted in the axils of the lateral veins. *Flowers 9 or 10 mm. broad, the calyx lobes glandular* 11.
10. Young branches more or less pubescent; pubescence of the leaves usually neither more abundant along the midrib than elsewhere, nor tufted in the axils of the lateral veins. *Flowers 6 to 10 mm. broad, the calyx lobes eglandular*..... 17.
11. Leaves lanceolate to ovate-lanceolate, rather strongly conduplicate or trough shaped. Fruit ripening in July and August.. *P. reverchonii*.
11. Leaves ovate to oblong-ovate or sometimes slightly obovate, usually not trough shaped. Fruit ripening in June..... *P. rivularis*.
12. Leaves usually 6 to 10 cm. long. *Calyx lobes glandular*..... *P. munsoniana*.
12. Leaves mostly 2 to 6 cm. long. *Calyx lobes eglandular*..... 13.
13. Leaves oblong-lanceolate to obovate-lanceolate, mostly 4 to 6 cm. long. *Flowers 10 to 14 mm. broad. Fruit ripening at the Arnold Arboretum in September*..... *P. orthosepala*.
13. Leaves lanceolate, oval-lanceolate, or oblong-oval, 2 to 6 cm. long. *Flowers 8 to 12 mm. broad. Fruit ripening from the last of May, in the South, to the first of September (subsp. watsoni)* *P. angustifolia*.
14. Leaves lanceolate to oval-lanceolate or sometimes ovate or oval, not strongly reticulate veiny below, and glabrous or pubescent. *Flowering pedicels glabrous or only sparingly pubescent*..... 15.
14. Leaves ovate, oval, or nearly orbicular, rarely somewhat obovate, rather strongly reticulate veiny below, and pubescent. *Flowering pedicels strongly pubescent*..... 16.
15. Petioles mostly 7 to 12 mm. long. *Calyx lobes only slightly shorter than the tube. Tree of the northern Alleghenies and southern New England*..... *P. alleghaniensis*.
15. Petioles mostly 5 to 9 mm. long. *Calyx lobes mostly shorter than the tube. Tree of the Southern States*..... *P. umbellata*.
16. Leaves orbicular to oblong-orbicular, obtuse at the apex..... *P. gravesii*.
16. Leaves ovate or oval, rarely slightly obovate, usually acute at the apex..... *P. maritima*.
17. Leaves oval or lance-oval, rarely ovate or obovate-lanceolate, narrowed or rounded toward the base, petioles 5 to 8 mm. long. *Flowers 9 to 10 mm. broad, pedicels and calyx finely pubescent*..... *P. gracilis*.
17. Leaves ovate to oblong-ovate, usually rounded at the base, petioles 10 to 12 mm. long. *Flowers 6 to 7 mm. broad, pedicels and calyx glabrous or sparingly pubescent*..... *P. venulosa*.
18. Leaves lanceolate, oblong-lanceolate or oblong-oval, narrowed or rounded at the base, the apex acute or acuminate. *Flowering pedicels without subtending bracts, or when present the bracts minute, not foliaceous. Eastern and Rocky Mountain species*. *P. pennsylvanica*.
18. Leaves oblong-oval, obovate or rarely lanceolate, narrowed or even cuneate toward the base, obtuse or rarely acute at the apex. *Flowering pedicels subtended by small foliaceous dentate or lacinate bracts. Southwestern and Pacific coast species*.... *P. emarginata*.
19. Leaves usually narrowly oblanceolate-spatulate and acute..... *P. pumila*.
19. Leaves oblong-spatulate to oval or somewhat obovate, acute or obtuse..... 20.

20. Petioles 5 to 10 mm. long, leaves 3.5 to 7 cm. long, obtuse or sometimes acute at the apex. Fruit about 10 to 15 mm. in diameter. Eastern and northern species..... *P. cuneata*.
20. Petioles 5 to 6 mm. long, leaves 3 to 4.5 cm. long, acute or rarely obtuse at the apex. Fruit about 15 to 18 mm. in diameter. Western species..... *P. besseyi*.

DESCRIPTIONS OF THE SPECIES AND THEIR HYBRIDS.

PRUNUS NIGRA Ait.

(Canada plum.)

Prunus nigra Aiton, 1789, Hort. Kew., v. 2, p. 165.*Prunus borealis* Poir., 1804, in Lam. Encycl., t. 5, p. 674.*Prunus mollis* Torr., 1824, Fl. North and Mid. U. S., v. 1, p. 470.*Prunus americana nigra* Waugh, 1896, in Vt. Agr. Exp. Sta. Bul. 53, p. 58.*Cerasus borealis* Michx., 1803, ? Fl. Bor. Amer., t. 1, p. 286.*Cerasus nigra* Lois., 1812, Nouv. Duham., v. 5, p. 32.

Leaves (Pl. I, fig. 2) oval or obovate, mostly 8 to 13 cm. long, 4.5 to 7 cm. broad, rounded at the base, abruptly acuminate toward the apex, green and glabrous above, or with scattered hairs along the veins, pale and becoming glabrous below except along the midvein and in the axils of the lateral veins, or sometimes with scattered hairs along the lateral veins, when young usually somewhat pubescent above and rather strongly so below, rarely entirely glabrous, the margins rather coarsely and unevenly serrate, the serrations rounded and in the young leaves glandular, the glands usually remaining as small callous points; petioles 10 to 18 mm. long, pubescent on the upper surface with longish hairs, or sometimes entirely glabrous, glands one to three near the apex or often entirely absent; stipules linear or sometimes lobed, the margins glandular. Flowers 2 to 2.5 or sometimes even 3 cm. broad, appearing before the leaves from the last of April in the southern portion of its range to the last of May in northern localities; umbels nearly sessile, mostly 2 or 3 flowered; pedicels 10 to 20 mm. long, usually about 18 mm., glabrous or very rarely finely pubescent in some western material; calyx usually somewhat reddish, in age frequently conspicuously so, the tube rather narrowly obconic, about 3.5 to 4 mm. long, or in cultivated trees the tube and lobes sometimes each 5 mm. long, glabrous, calyx lobes oblong-ovate or oblong-obtuse, glandular serrate, glabrous or rarely pubescent on the inner surface mainly toward the base, and still more rarely with a few scattered hairs on the outer surface, the lobes at length spreading or reflexed; petals white or in age with a decided tinge of pink, oblong-ovate to nearly orbicular and abruptly contracted to a claw, 10 to 12 mm. long, 6 to 10 mm. broad, usually crose toward the apex, sometimes conspicuously so. Fruit oblong-oval, 2.5 to 3 cm. long, 1.8 to 2.5 cm. in diameter, orange red or sometimes deep crimson, varying to orange yellow, nearly destitute of bloom,

ripening from the second week in August to the end of September; stone (Pl. IX, figs. 1 to 7) oblong-oval, rather flat, about 20 mm. long, 14 mm. broad, obliquely truncate at the base and rounded at the apex, grooved on either side a short distance from the ventral edge, and with a single groove along the dorsal edge.

Prunus nigra is a small tree, attaining a maximum height of about 30 feet. It sprouts from the roots and frequently forms small thickets. The grayish bark of the trunk exfoliates in platelike scales, while that of the young twigs is smoother and very dark gray. The branches are often furnished with spinescent branchlets, and the winter buds are lanceolate in outline, acute, and 4 to 5 mm. long. The wood is heavy, close grained, and strong.

While *Prunus nigra* has often been confused with *P. americana*, it is nevertheless one of the most distinct and easily recognizable of the native species. The foliage is distinguished from the latter species by the rounded instead of pointed serrations of the leaves. The flowers are larger, have a more pinkish tinge when fading, and appear earlier in the same locality; the calyx lobes are glandular serrate and usually glabrous, while in *P. americana* they are inconspicuously glandular or eglandular and pubescent within.

*Prunus nigra*¹ grows (fig. 1) in the alluvial valleys of streams or often on limestone hills, and ranges from the vicinity of the St. John River in western New Brunswick through Maine, excepting the extreme northern portion, to the valley of the St. Lawrence and westward to the southern shores of Georgian Bay and nearly to the shores of Lake Michigan in the southern peninsula of the State of Michigan. It extends southward to central Massachusetts, though probably as an introduced plant in that State, but occurs apparently as a native at Ithaca, N. Y., and in northern Ohio near the Black River, in Lorain County; thence its line of southern distribution moves northward to the vicinity of Lake St. Clair, Lansing, and Grand Rapids, Mich. It does not occur in the sandy soils of the lake region of western Michigan, but reappears in northeastern Illinois, extending from near Joliet to the southern part of Dodge County and the vicinity of Milwaukee, in southeastern Wisconsin. It does not appear to have been observed in central Wisconsin, but is found in the western part of the State, where it extends northward from the vicinity of the Wisconsin River and through eastern Minnesota to the region west of Port Arthur, in western Ontario, and to the Winnipeg Valley, where it was collected by Bourgeau in 1857.

¹ Although this species is reported by Hooker (33, p. 168) from Newfoundland, Dr. M. L. Fernald, who has collected extensively in New Brunswick and Newfoundland, writes that he has no knowledge of it east of the St. John River system. He says: "It is fairly abundant on terraces and limey slopes near the mouth of the Aroostook River, which is its northeastern limit, I think." The herbarium material examined confirms this view of the northeastern limit of the species.

While not the first American species to come to the notice of European explorers, *Prunus nigra* was nevertheless one of the earliest, having been observed by Jacques Cartier in the possession of Indians whom he met in the Bay of Chaleur on the occasion of his first voyage to America in 1534. Again on his second voyage Cartier found trees near the Isle of Orleans, and as late as 1895 the species still grew in the vicinity, specimens having been collected on the island by J. G. Jack, of the Arnold Arboretum.

Notwithstanding the fact of its being seen by the early European voyagers, the species did not receive botanical description until 1789, when it was described briefly by William Aiton from cultivated specimens. It is said by Aiton to be a "native of Canada" and to have been introduced into English gardens by Lee & Kennedy, nurserymen

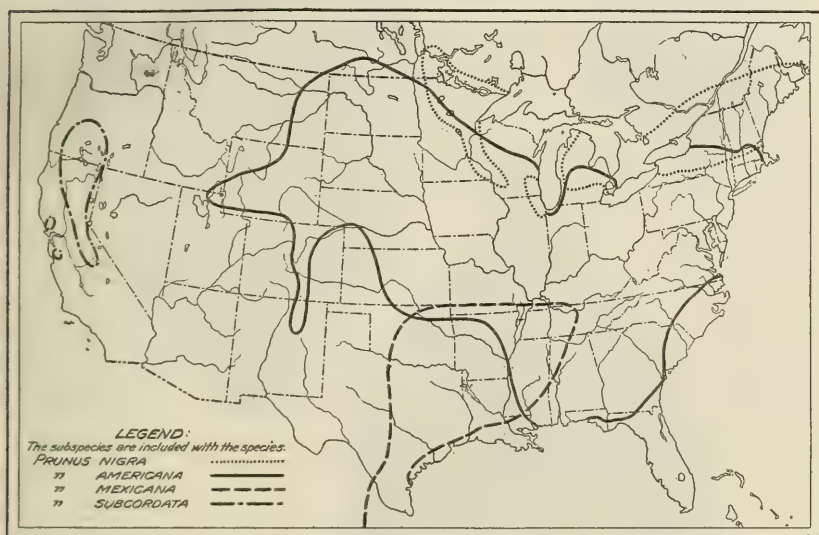


FIG. 1.—Outline map of the United States, showing the distribution of native American species of *Prunus: Nigra, americana, mexicana, and subcordata.*

at Hammersmith, near London. Its introduction on the Continent may have been somewhat earlier, for it is this species that is figured by Poiteau and Turpin (20) as *La Galissonnière, Prunus hiemalis*. These authors state that M. de la Galissonnière was sent to Canada as governor by Louis XV in 1750 and that seeds were sent by him which were planted in the "Jardin du Roi, à Paris." Though the date of introduction is not given, it must have occurred within a few years, for Galissonnière remained in Canada but a short time. In fact, it is quite possible that Lee & Kennedy obtained the species from France. The type specimen is at the Natural History Museum, London. The habitat of *Cerasus borealis* Michx.¹ is given as

¹ Bailey, L. H. C., p. 193. "Of his [Michaux's] *Cerasus borealis* there are two things on the sheet, but they are both forms of *P. hortulana*."

"in America boreali et in altis montibus Novae Angliae," and the type specimen is probably in the Michaux herbarium at the Muséum d'Histoire Naturelle de Paris. Michaux's description is scarcely distinctive, but if he really had a specimen from the mountains of New England it could not be other than *Prunus nigra*. *P. mollis* was described by John Torrey from a specimen collected by Chester Dewey "in Massachusetts, on the road from Williams College to Troy." This specimen is preserved in the Herbarium of Columbia University, at the New York Botanical Garden, Bronx Park, New York City. The legend on the sheet reads "I found this on the road to Troy and the people said it was not set out as they believed, for it is common in the woods." The specimen is unquestionably *P. nigra*.

Prunus nigra is grown locally in various parts of Canada and the fruit is sold on the markets in many of the cities, yet it has given rise to very few named varieties and has not occupied the place in American horticulture which it deserves. The strength of the wood enables the tree to withstand the heavy snows and severe storms of Canada with less injury from breaking than is the case with *P. americana*, and this fact with its hardiness should commend it for regions subject to such conditions.

The varieties Aitkin, Cheney, Crimson, Itasca, Odegard, Oxford, Smith Red, Snelling, and Whyte, although showing slight differences, are typical of the species. The varieties Hanson and Wazata have leaves narrower in proportion to their length and with more unequal serrations; these are rounded, however, and the calyx characters are those of *Prunus nigra*. Similar specimens have also been collected in a wild state.

PRUNUS AMERICANA Marsh.

(Wild plum.)

Prunus americana Marsh., 1785, Arb. Amer., p. 111.

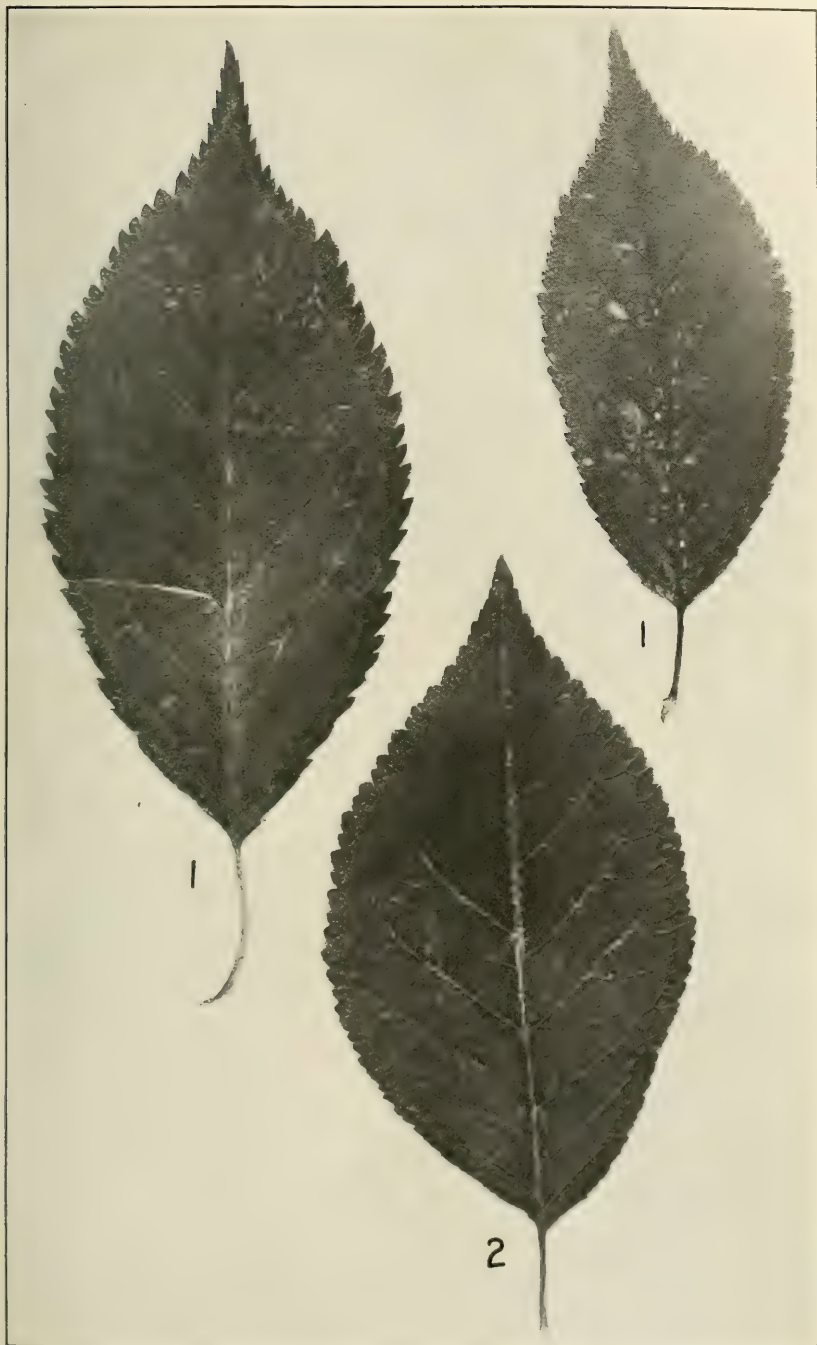
Prunus latifolia Moench, 1785, Verz. Ausl. Bäume, p. 85.

Prunus hiemalis Michx., in part, 1803, Fl. Bor. Amer., t. 1, p. 284.

Cerasus americana Hook. and Arn., 1835, in Comp. Bot. Mag., v. 1, p. 24.

Prunus ignotus [ignota] Nelson, 1906, in Bot. Gaz., v. 42, no. 1, p. 53.

Leaves (Pl. I, fig. 1) oval or sometimes oblong-oval to narrowly obovate, 6 to 10 cm. long, 2.5 to 5 cm. broad, acuminate toward the apex and usually rather gradually narrowed at the base, green and glabrous above, pale and glabrous below, except along the midvein, or entirely glabrous or rarely thinly and inconspicuously pubescent, the margin sharply and sometimes doubly serrate; petioles 7 to 14 mm. long, pubescent along the upper surface or sometimes glabrate, eglandular, or with one or two glands near the apex; stipules linear or lobed and the lobes linear, glandular along the margin. Flowers 18 to 25 mm. broad, in nearly sessile umbels of 3 to 4, appearing with



LEAVES OF THE NATIVE AMERICAN SPECIES OF PRUNUS.—1: 1, PRUNUS AMERICANA; 2, P. NIGRA.
(Natural size.)



LEAVES OF THE NATIVE AMERICAN SPECIES OF PRUNUS.—II: 1, *PRUNUS MEXICANA*; 2, *P. SUBCORDATA*.
(Natural size.)

the leaves from the first week in April in the South to the latter part of May and before the leaves in the northern part of its range; pedicels slender, mostly 7 to 15 mm. long, glabrous; calyx tube obconic and about 3 mm. long, glabrous or inconspicuously pubescent, the lobes as long or slightly longer than the tube, lanceolate or oblong-lanceolate, obtuse or sometimes acute, obscurely glandular on the margin mainly above the middle, or sometimes eglandular, dentate toward the apex, glabrous or inconspicuously pubescent on the outer and soft-pubescent on the inner surface, reflexed at anthesis; petals oblong-oval or obovate and narrowed to a claw, mostly 8 to 10 mm. long, 4.5 to 6 mm. broad, entire or obscurely erose toward the apex, sometimes slightly ciliate near the base. Fruit extremely variable in the time of ripening, ranging from early in July in the South and from the end of August to early October in the North, subglobose or sometimes even somewhat oblate to slightly elongated, 1.8 to 2.5 cm. long, varying from reddish orange to red, marked with numerous minute, whitish dots and with a bluish bloom or sometimes nearly destitute of bloom, skin rather thick and tough, flesh yellow; stone (Pl. VIII, figs. 1 to 16) oval, turgid, 13.5 to 16 mm. long, 10 to 14 mm. broad, narrowed at the base and pointed or sometimes rounded at the apex, grooved on either side a short distance from the ventral edge, sometimes also with a slight ridge on either side and a shallow groove along the ventral edge as on the dorsal, the surface smooth or sometimes obscurely rugose.

The tree reaches a maximum height of about 35 feet with a trunk diameter of about 12 inches. It sometimes grows singly, but more often sprouts from the roots and frequently forms thickets of considerable extent. The branches are more or less spinescent, spreading, or often somewhat drooping toward the extremities, bark of the trunk dark brown, exfoliating in platelike scales, that of the young twigs chestnut colored and eventually turning dark brown; winter buds 3 to 4 mm. long, narrowly ovate, acute. The wood is heavy, close grained, and fairly strong.

Prunus americana is distributed (fig. 1) from central Massachusetts and central New York westward to central Michigan and northern Indiana, thence northwestward to the vicinity of Brandon, Manitoba. It reaches its extreme western limit in the vicinity of Logan in northern Utah, and occurs along the eastern foothills of the Rocky Mountains in Colorado extending southward to Las Vegas in New Mexico. It apparently does not occur in the dry region of eastern Colorado or in the extreme western part of Kansas, but farther east it extends southward to southern Kansas and through central Missouri, while east of the Mississippi River it extends southward nearly to the Gulf, in Mississippi and Alabama. It is found in northern Florida, but does not occur in the peninsular part of the

State. It evidently reaches nearly to the coast in the vicinity of Savannah, Ga., but is not found in the Coastal Plain of the Carolinas.

With the possible exception of *Prunus pennsylvanica*, *P. americana* is the most widely distributed of any of the native species, and it appears also to be one of the most variable. In the Eastern States it grows mainly in rich alluvial soils, in the Southern States it is frequently met with in the mountain region, but sometimes occurs in river swamps, while in the prairie States of the Mississippi Valley it is found on bottom lands and sometimes on dry uplands. Toward its western limits it is smaller and often assumes even a shrublike appearance. Material of the species from the western portion of its range indicates a form having leaves usually more glabrous and of a lighter green color, with a greater tendency to fold in drying. In the East the calyx lobes are usually glandular and minutely toothed toward the apex, while west of the Mississippi River the calyx lobes are usually, though not always, eglandular and entire. There is also a tendency for the stone in eastern specimens to be shorter in proportion to its breadth and more turgid than in western material. There are so many exceptions to the constancy of these characters in a definite geographical region, however, that it seems unwise, and in fact apparently impossible, to distinguish any form, even as a subspecies. In southwestern Missouri a grove was found, the trees of which appeared rather different from others in that vicinity. These trees were 10 to 15 feet high; leaves oval-lanceolate to lanceolate, 5 to 7 cm. long, 2 to 3 cm. broad, rather long acuminate at the apex, gradually narrowed toward the base, green and glabrous above, pale and rather loosely pubescent below; flowers about 12 mm. broad, pedicels 6 to 8 mm. long, glabrous, calyx entirely glabrous on the outer surface, tube about 2 mm. long, the oblong lobes about as long, obtuse, ciliate on the margin, eglandular, hairy within, at least toward the base; petals 5 to 6 mm. long, oblong-oval to oblong-cuneate; fruit globose.

Prunus americana was probably the first American species to be described botanically, for it is apparently included by Plukenet in 1696. It was not named binomially until 1785, when it was described by Marshall. So far as known, no types of Marshall's plants are in existence, but there can be little possibility of mistaking the identity of his species in this case, and his material doubtless came from eastern Pennsylvania. *Prunus latifolia* was described by Moench in the same year in which Marshall's *Arbustrum* was published. Moench described his species from material grown from seed obtained in America. *P. hiemalis* was described from "Canada, Virginia et in umbrosis Carolinae." *P. ignota*, based on specimens collected by C. S. Crandall on the banks of the Cache la Poudre, near Fort Collins, Colo., does not differ from the species.

It has been suggested by Tuckerman (35, p. 99) in his comments on the plants mentioned by Josselyn in 1672, that the following reference to plums by that author included *Prunus americana* as well as *P. maritima*:

Plumb Tree, several kinds, bearing some long, round, white, yellow, red, and black plums; all differing in their Fruit from those in England.

Nevertheless, all the colors described except white occur in *P. maritima*, and it is doubtful if *P. americana* is indigenous to eastern Massachusetts. It is therefore quite possible that Josselyn had seen only *P. maritima*.

Horticulturally, *Prunus americana* is one of the most important species and has probably received the greatest attention. A large number of varieties have been named, and these have originated almost entirely in the Middle West, where the fruit apparently is of better quality than is the case in the eastern part of its range. Most of the varieties also show an elongated stone, but since a larger fruit is almost invariably accompanied by a larger and longer stone, this does not necessarily indicate a distinct form, as might be inferred from a study of cultivated material alone. In this connection, L. H. Bailey (2, p. 3) says:

Notwithstanding its wide range, most of its cultivated varieties have come from its northwest limits, as northern Illinois, Wisconsin, Minnesota, Iowa, and Kansas. This fact is an indication that the western plum may be a distinct species from the eastern and southwestern types, and I should not be surprised if we ultimately find this to be true. I have looked in vain, however, for characters with which to separate them.

Among the varieties belonging to this species may be mentioned the following: Advance, Atkins, Blackhawk, Brittlewood, Crescent City, Deep Creek, De Soto, Eaton, Forest Garden, Hawkeye, Hunt, Iowa Beauty, Mollie, Ocheeda, Stoddard, and Weaver.

PRUNUS AMERICANA HYBRIDS.

Among cultivated varieties there are apparently several hybrids of *Prunus americana* with *P. triflora* (Pl. XIII, fig. 9) and a smaller number with *P. angustifolia watsoni*, *P. besseyi*, *P. hortulana*, *P. hortulana minor*, *P. munsoniana*, *P. pumila*, *P. simonii*, and $\times$ *P. utahensis* (*P. besseyi* $\times$ *angustifolia watsoni*). (Pl. XIII, fig. 14.) Some of these show much promise horticulturally for some sections of the West.

PRUNUS AMERICANA LANATA Sudworth.

Prunus americana lanata Sudw., 1897, U. S. Dept. Agr., Div. Forestry Bul. 14, p. 237.

Prunus americana mollis Torr. and Gray, 1840, Fl. N. Amer., v. 1, p. 407, in part.

Prunus lanata Mackenz. and Bush, 1902, Man. Fl. Jackson Co., Mo., p. 109.

Leaves ovate to oblong-ovate or oblong-oval, rarely slightly obovate, mostly 6.5 to 10 cm. long, 3 to 6 cm. broad, narrowed at the base, acuminate at the apex, the margins sharply serrate, appressed pubescent above or sometimes glabrous, densely pale soft-pubescent below or rarely thinly pubescent, the pubescence usually becoming fuscous with age; petioles rather stout, usually 9 to 16 mm. long, pubescent or glabrate, eglandular or with one or two glands near the apex and the glands often short stalked. Flowers 15 to 20 mm. broad, in umbels of 3 to 4, the pedicels 9 to 12 mm. long and glabrous or pubescent; calyx usually appressed pubescent or sometimes nearly or quite glabrous, the tube campanulate, about 3 mm. long, the obtuse lobes as long as the tube, soft-pubescent within, eglandular and entire or minutely and obscurely dentate toward the apex, reflexed in age; petals oblong oval, 8 to 9 mm. long, narrowed to a usually rather long claw. Fruit similar to that of *Prunus americana*; stone 15 to 22 mm. long, 11 to 13 mm. broad, oval and grooved as in the species.

Prunus americana lanata is occasionally found in Illinois, but more commonly in southern Iowa and southward to southern Missouri.

The name *Prunus americana lanata* Sudworth was based on *P. americana mollis* Torrey and Gray, not *P. mollis* Torrey, which is identical with *P. nigra* Aiton.

The subspecies or variety *mollis* as established by Torrey and Gray was evidently intended to include the forms with large pubescent leaves and probably included in addition to the present subspecies *Prunus nigra* and *P. mexicana*. Later authors restricted the name to *P. mexicana* and the pubescent form of *P. americana*, while Bush and Mackenzie in their use of the name *lanata* definitely applied it, in the "Flora of Jackson County, Mo.," to the hairy form of *P. americana*. In the same year these authors (49, p. 83) in another publication give the following as the range of *P. lanata*: "Common along rivers and bottoms from Illinois and Iowa to Missouri, Texas, and Mexico." The inclusion of Texas and Mexico refers to *P. mexicana*. Torrey and Gray did not give the distribution of the variety separately from the species which was: "Banks of streams and in hedges, Canada! (from the Saskatchewan!) and New England States! to Georgia and Louisiana! and Texas!" There can be no question of the application of the name *lanata* to this form as a proposed species, and it is therefore retained as the name of the subspecies. There is apparently no character which is constant and definite enough to distinguish this form as a species. The quantity of pubescence is extremely variable and though the calyx lobes are usually entire and eglandular that is sometimes the case with the species. It is mainly only the more marked pubescence, variable though it may be, that can be relied on as the distinguishing character.

Few horticultural varieties belong to the subspecies, but American Eagle, Quaker, Van Buren, and Wolf are referable to it.

PRUNUS MEXICANA Wats.

(Big-tree plum.)

Prunus mexicana Wats., 1882, in Proc. Amer. Acad. Sci., v. 17 (n. s. v. 9), p. 353.

Prunus americana mollis Torr. and Gray, 1840, Fl. N. Amer., v. 1, p. 407, in part.

Prunus australis Munson; Waugh, 1898, in Bot. Gaz., v. 26, no. 1, p. 52.

Prunus reticulata Sarg., 1911, Trees and Shrubs, v. 2, pt. 3, p. 151, t. 162.

Prunus tenuifolia Sarg., 1911, Trees and Shrubs, v. 2, pt. 3, p. 153, t. 163.

Prunus polyandra Sarg., 1911, Trees and Shrubs, v. 2, pt. 3, p. 155, t. 164.

Prunus arkansana Sarg., 1911, Trees and Shrubs, v. 2, pt. 3, p. 157, t. 165.

Leaves (Pl. II, fig. 1) oblong-obovate or obovate, mostly 7 to 10.5 cm. long, 4 to 6.5 cm. broad, the margin sharply serrate or sometimes doubly serrate, rounded or even subcordate at the base and acute or abruptly acuminate toward the apex, yellowish green, and soft-pubescent above with short appressed hairs at least when young, pale green below and more strongly pubescent with longer hairs, veins at length rather prominent or sometimes strongly reticulate below and often in age appearing somewhat rugose above; petioles usually stout, velutinous, though sometimes sparingly so, mostly 10 to 12 mm. long, usually with one or more short-stalked glands at or near the apex or rarely on the base of the leaf blade; stipules usually lobed, the lobes linear and glandular serrate. Flowers about 15 to 18 mm. broad in nearly sessile umbels of 2 to 4; pedicels glabrous or rarely pubescent, usually 9 to 12 mm. or sometimes even 15 mm. long; calyx campanulate, the upper part of the tube and lobes soft-pubescent with short hairs, the tube 2.5 to 3 mm. long, the lobes oblong or ovate-oblong and as long as the tube or nearly so, dentate at the apex or sometimes entire, obscurely glandular in the margin, rather strongly pubescent within, at least toward the base, and usually reflexed; petals mostly 6 mm. to very rarely 10 mm. long, sometimes sparingly and obscurely pubescent on the outer surface toward the base, varying even in the same specimen from ovate-orbicular and abruptly contracted to a short claw to oblong-oval and gradually narrowed to a claw, the margin usually entire. Fruit ripening in October and November, rarely earlier, globose or very rarely oblong, 18 to 30 mm. in diameter or rarely larger, dark purplish red with bluish bloom; stone (Pl. VIII, figs. 17 to 24) obovoid to nearly round, 12.5 to 16 mm. long, 10 to 12 mm. broad, turgid, usually pointed at the base and rounded at the apex or sometimes slightly pointed, slightly grooved on either side a short distance from the ventral edge and inconspicuously grooved, or the groove entirely absent along the dorsal edge, surface smooth, except for a few usually indistinct ridges toward the base.

The tree attains a maximum height of about 40 feet and occurs singly or in groves, but never suckers or forms thickets. The bark of the trunk exfoliates in platelike scales when young, later becoming furrowed, while the larger branches retain the bark character of the young trunk; the bark of the twigs at flowering is usually grayish, that of the young growth in summer dull chestnut.

Prunus mexicana occurs (fig. 1) in open woods in rich alluvial bottom lands, on the upland prairie soils, and even in sandy loam, and ranges from southwestern Kentucky and western Tennessee southward through northwestern Louisiana to the vicinity of Lerios, Coahuila, Mexico, the type locality, and central Nuevo Leon, where scattered trees occur on the northern slope of the Sierra Madre at about 3,000 feet elevation. Its range extends westward through the extreme southern part of Missouri to central Oklahoma and central Texas.

Prunus mexicana varies somewhat, but not more so than may be expected in a species of its range. Specimens from Feliciana Parish, La., have the calyx tube entirely glabrous, except for a few longish hairs toward the base, with pedicels 17 to 18 mm. long. The calyx tube in Arkansas specimens, *P. polyandra* and *P. arkansana* Sarg., is less pubescent than is usual in Texas material, but is somewhat variable in this respect even in the same locality. A form, *P. tenuifolia* Sarg., in the vicinity of Larissa, Cherokee Co., Tex., shows the greatest departure from the usual character of the species of any observed, since it has a finely pubescent calyx with a few longish hairs toward the base and on the pedicels, while the immature fruit indicates an oblong stone. *P. reticulata* Sarg., was described from Grayson County, Tex. The original material of the species published by Sargent has been studied, and the characters on which they are based were very carefully considered. They are all of the type known as the big-tree plum, and horticulturally these differences are of less importance than variations in what is still recognized as a single species in *P. americana*. The rank to be assigned the forms under discussion depends upon one's conception of what constitutes a species.

Although long confused with *Prunus americana* and in the herbarium sometimes difficult to distinguish from *P. americana lanata*, the species is nevertheless a very distinct one. It never forms thickets, as does *P. americana* and its subspecies, but occurs always as a tree with a well-defined trunk, which in the older trees differs in its furrowed bark. The young leaves as they appear are mostly somewhat obtuse at the apex instead of acuminate; the older leaves are usually broader in proportion to their length, and the serration of the margin is slightly less pronounced. The flowers also have petals somewhat broader in proportion to their length than in *P. americana*, while the stone is obovoid or round and more turgid.

Horticulturally, the species has received little attention, though the fruit is gathered from the wild trees and made into preserves. The fruit is variable in size and quality, and a careful search for desirable forms might form the basis for the development of late-ripening varieties of value in some of the Southern States. It is apparently more susceptible to frost injury than *Prunus reverchonii* and, though drought resistant to an appreciable extent, is probably less so than the latter species. It has been used as a stock in the nursery of T. V. Munson at Denison, Tex., with very satisfactory results, and its vigor and nonsuckering character may lead to its further use.

PRUNUS MEXICANA HYBRIDS.

Prunus mexicana has been hybridized with *P. triflora*, and wild trees in the vicinity of Henrietta, Tex., are apparently hybrids with *P. reverchonii*. One of these has been named horticulturally and for a time was offered by several nurseries, but it has little to commend it.

PRUNUS SUBCORDATA Benth.

(Pacific or western wild plum.)

Prunus subcordata Benth., 1848, Pl. Hartw., p. 308.

Prunus subcordata kelloggii Lemmon, 1890, in Pittonia, v. 2, p. 67.

Leaves orbicular (Pl. II, fig. 2), oblong-orbicular, or sometimes ovate, rounded, subcordate, or rarely gradually narrowed at the base and usually rounded and obtuse at the apex, 2.5 to 5 cm. long, 1.5 to 4 cm. broad, the margins incisely serrate, sometimes doubly so, the teeth at first gland tipped, the glands usually falling away in age, leaving the serrations more or less obtuse, or more rarely the serrations acute, the young leaves usually pubescent, at least below, becoming glabrous as they mature or sometimes remaining rather strongly pubescent below, even in age; petioles 7 to 12 mm. long, glabrous or pubescent, glandular near the apex or sometimes the glands on the base of the blade; stipules lanceolate with glandular margins. Flowers 15 to 18 mm. broad, in umbellike clusters of 2 to 4, appearing with the leaves from the first of April to about the middle of May, according to the locality; pedicels and calyx pubescent or glabrous, the pedicels 7 to 13 mm. long; calyx tube campanulate, about 3 mm. long, the lobes usually slightly longer, oblong or oblong-obovate, obtuse, and glandular-serrate, usually glabrous within; petals entire, 7 to 9 mm. long, oblong or obovate and abruptly contracted to a short claw. Fruit ripening in August or September, slightly oblong, 1.5 to 3 cm. long, dark red, purplish red, or rarely yellow, variable in quality, though often excellent; stone oblong, oval (Pl. IX, figs. 8 to 15), or rarely somewhat orbicular, 12 to 18 mm. long, 10 to 17 mm. broad, oblique or somewhat pointed at the base and rounded with an obscure point at the apex, variously ridged

and grooved near the ventral edge, rather conspicuously grooved along the dorsal edge, somewhat ridged toward the base, and the surface obscurely roughened.

Prunus subcordata is often only a shrub 3 to 10 feet high with crooked stem and branches. In moist fertile soils it grows to a height of 15 to 25 feet. It often forms extensive thickets or clumps. The bark of the trunk is grayish brown, furrowed, and somewhat scaly; the main branches are rather thick and start out nearly horizontally from the trunk. The young twigs are reddish, either glabrous or pubescent, and marked with orange-colored lenticels.

The species is found (fig. 1) in central Oregon and northeastern California, thence southward along the western slope of the Sierra Nevada to the Yosemite Valley, where it occurs at an altitude of 4,000 feet, in the coast ranges of California in Lake County, in the hills east of Santa Rosa, and on Black Mountain, Santa Clara County.

Prunus subcordata was originally described from the upper valley of the Sacramento, where it appears to have been first collected by Karl Theodor Hartweg in 1836 or 1837.

Prunus subcordata kelloggii does not appear to show any botanical differences from the type. The larger size of the tree and the larger and superior quality of the fruit ascribed to the proposed subspecies are not correlated with any other character; and these are variations that occur in all the species of the genus. The author of this supposed form says of it:

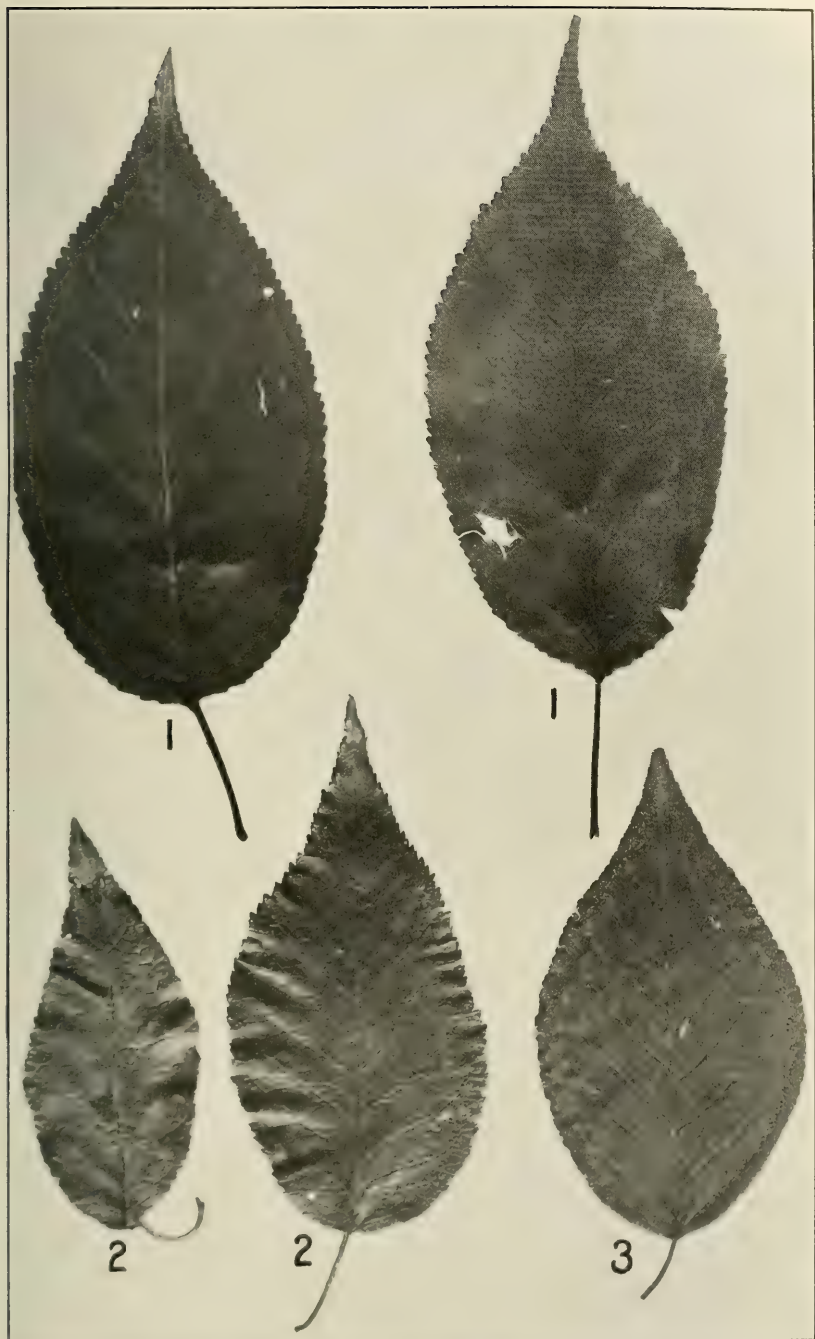
The variety is abundant near Sierra City, Sierra Co., Cal., where along with the type the writer has observed it almost annually since 1867. It prevails generally in the more northerly parts of the state, and has long been observed and its superior qualities noted by my friend Mr. Sisson, of Strawberry Valley at the base of Mt. Shasta, where it grows plentifully along streams that course through rich meadow lands. Dr. Kellogg described it, though without giving it a varietal name, as early as 1859, in Hutching's Magazine * * * [36].

Since Hutching's Magazine is a somewhat rare publication, it may be of interest to quote what Dr. Kellogg writes concerning this plum:

It is very probable that many of our readers who dwell in the principal mercantile cities are unaware that in the mountains of this state there are not less than two varieties of a very excellent wild plum. One is almost the size—although we have seen some much larger—and shape of that given in our engraving, the other is a little smaller, oblong, and almost the shape and color of a damson when ripe. This latter variety has not yet been examined and classified by botanists; but if some of our friends who are coming to the city will bring a good specimen with them and leave it with us, we will see that this is done.

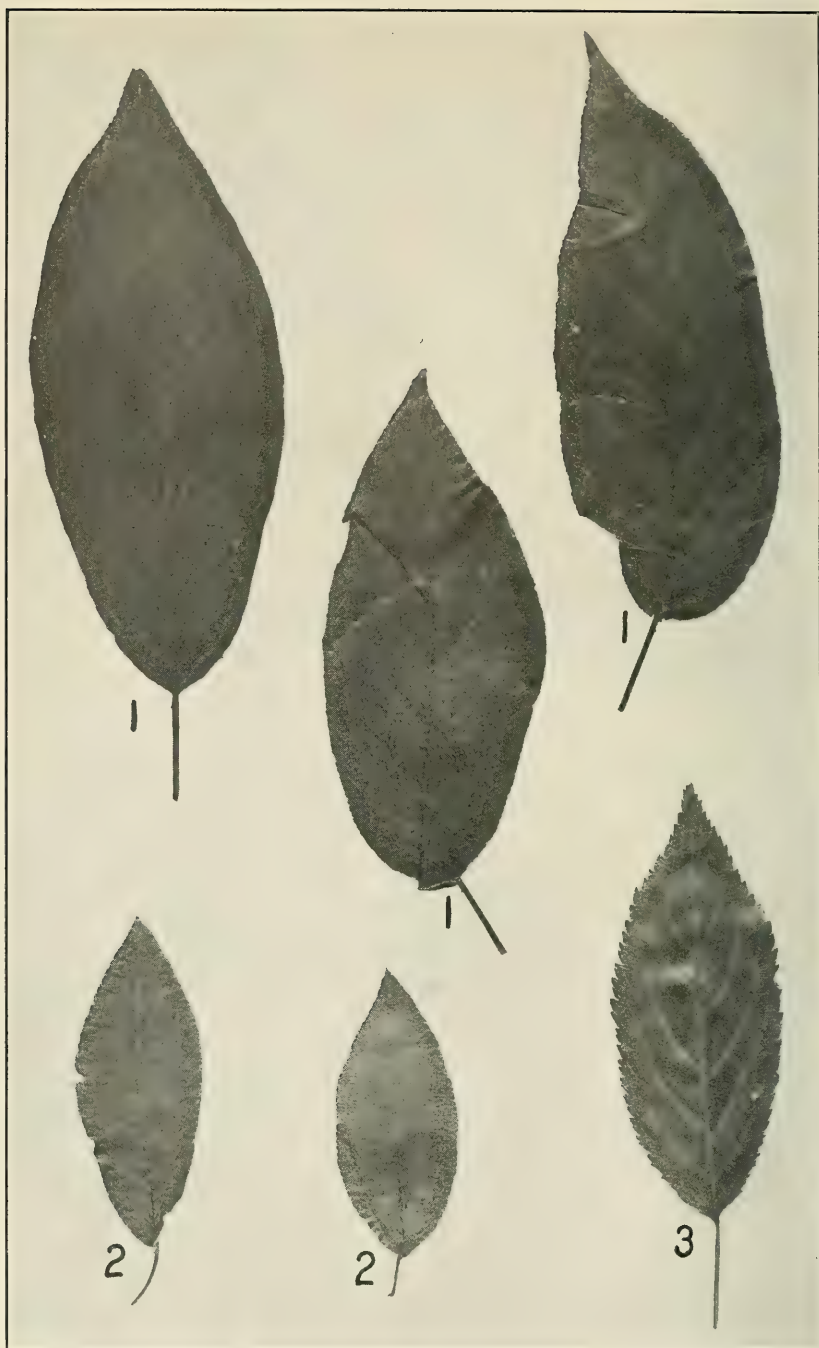
Both varieties of this plum grow on low bushes and not on trees like other wild plums at the east, and are about the height and conformation of the illustration given on page 10.

They generally grow in patches or groups, at the heads of ravines, at an altitude seldom less than 2,000 feet above the sea, and mostly in open localities adjacent to



LEAVES OF THE NATIVE AMERICAN SPECIES OF PRUNUS.—III: 1, *PRUNUS HORTULANA*; 2, *P. REVERCHONII*; 3, *P. RIVULARIS*.

(Natural size.)



LEAVES OF THE NATIVE AMERICAN SPECIES OF PRUNUS.—IV: 1, PRUNUS MUNSONIANA;
2, P. ANGUSTIFOLIA; 3, P. ORTHOSEPALA.
(Natural size.)

pine forests, but not directly in it. The bushes are found near to each other, and the two varieties frequently grow in the same group, though not from the same root.

Both are excellent edibles, although those that are round are the first ripe and better, eaten as fruit or stewed as sauce, and preferred by some palates; but when the oblong plum is thoroughly ripe, its rich acetous flavor, in our estimation, far excels the other and makes a delicious preserve.

Just before the fruit is fit for use, a large proportion of its leaves drop off, when, by drawing the hand up the small twiglike boughs, an immense quantity can be gathered in a brief space of time.

For some unexplained reason, like the coffee tree of northwestern Mexico, they do not always bear fruit two years successively.

These wild plums could be cultivated to advantage in our gardens and would make a pleasing variety of fruit in our markets; and for grafting purposes, might be more hardy and serviceable than the other, as best adapted to their native soil and climate, especially in a mountainous region.

The differences described for this subspecies are variations that occur in practically all the species of the genus and are horticultural rather than botanical in their nature. A careful study in the field also failed to reveal any characters by which a distinct form might be distinguished.

PRUNUS SUBCORDATA HYBRID.

A variety named Glow, recently originated by Luther Burbank, is described by the originator as a combination of *Prunus triflora*, *P. maritima*, *P. americana*, *P. subcordata*, and *P. nigra*.

PRUNUS SUBCORDATA OREGANA (Greene) W. F. Wight.

Prunus oregana Greene, 1896, in *Pittonia*, v. 3, pt. 15, p. 21.

Leaves oval or ovate, about 3 cm. long, pubescent, at least on the lower surface; fruit pubescent even when mature, otherwise similar to the species.

Originally described from specimens collected in 1893 on the Klamath Indian Reservation, in southeastern Oregon, it has since been collected near Klamath Falls and in the Sprague River Valley. Since this differs from *Prunus subcordata* only in the fruit being more or less covered with pubescence, it is not considered worthy of specific rank.

PRUNUS HORTULANA Bailey.

Prunus hortulana Bailey, 1892, in *Gard. and Forest*, v. 5, p. 90.

Prunus hortulana waylandi Bailey, 1901, *Cycl. Amer. Hort.*, v. 3, p. 1450.

Leaves oblong-obovate acuminate (Pl. III, fig. 1) to oblong-oval or oblong and acuminate, rarely oblong-lanceolate, mostly 7.5 to 11 cm. long, 2.5 to 4.5 cm. broad, usually rather abruptly rounded at the base, yellowish green, glabrous and somewhat lustrous above, pale green and pubescent below, with tawny hairs at least along the midrib and lateral veins, the pubescence usually tufted in the

axils of the lateral veins often rather densely hairy when very young, serrations rounded or almost crenate, glandular; petioles mostly 1.5 to 2.5 cm. long, pubescent on the upper surface, usually with one or more glands toward the apex; stipules linear and glandular serrate. Flowers appearing from the first of April in southern Missouri to the middle of May in northern localities, in umbels of 2 to 4 or rarely 5, about 12 to 15 mm. broad; pedicels glabrous, slender, 9 to 12 or sometimes even 14 mm. long; calyx campanulate, the tube about 3 mm. long, obscurely ribbed, and glabrous, the lobes nearly or quite as long as the tube and oblong-ovate, glabrous or sometimes obscurely pubescent, glandular on the margin, mostly obtuse at the apex, pubescent within mainly toward the base, and usually reflexed in age; petals 6 to 8 mm. long, oval or oblong-orbicular, usually rather abruptly narrowed to a claw. Fruit ripening late in July under cultivation in Texas, in September in Missouri, and often in October in northern localities, globose or rarely slightly ellipsoid in wild specimens, 18 to 25 mm. in diameter, or in the ellipsoid forms 30 mm. long, varying in color from red to yellow and usually marked with whitish dots, bloom thin or wanting, flesh firm; stone extremely variable (Pl. X, figs. 1 to 12), ranging from nearly globose,¹ 11 by 9 by 7 mm., to oval or oblong, 17 by 11 by 7.5 mm., pointed or narrowed and truncate at the base, pointed or sometimes rounded at the apex, the ventral edge usually rather sharp, variously grooved and sometimes ridged on either side, grooved along the dorsal edge, the surface reticulated or rarely obscurely so.

The tree grows singly or in groves and attains a maximum height in the region of its greatest perfection of about 25 or 30 feet; bark of the trunk rather thin, exfoliating in platelike scales, dark brown, the inner layers reddish; young twigs at time of flowering rather dark reddish brown or chestnut colored, sometimes with grayish blotches. In the character of foliage, in the shape of fruit and stone, and in the time of ripening *Prunus hortulana* bears some resemblance to *P. reverchonii*, but it does not sucker as that species does in its natural state and apparently never forms a thicket.

Prunus hortulana ranges (fig. 2) from central Kentucky and northwestern Tennessee westward to northeastern Oklahoma and eastern Kansas and northward through Missouri and western Illinois, reaching its northernmost limit in Scott County, Iowa. It is most abundant and apparently reaches its greatest size in Missouri.

Prunus hortulana was originally described from cultivated material, being based on the varieties "Golden Beauty, Cumberland, Garfield, Sucker State, Honey Drop, probably Wild Goose, and others."

¹ The globose form of the stone is represented among cultivated varieties by Reed, and the oval or oblong form by Golden Beauty, Wayland, and World Beater, with various intermediate shapes in other varieties as well as in wild material.

All of the varieties named, with the exception of the last one, are of the "Wayland group" and the name *hortulana* must in consequence be retained in its original application. Wild goose belongs to a distinct species, very different in habit and in some other characters from any of the other varieties named in the original description. The species varies greatly in the size and quality of its fruit, and when it receives the attention it deserves by those engaged in the improvement of American fruits it will undoubtedly occupy a more prominent place in American pomology than at present. In its most perfect development it is probably the most symmetrical in form of any of the native species. Its vigor, nonsuckering habit, and abundant

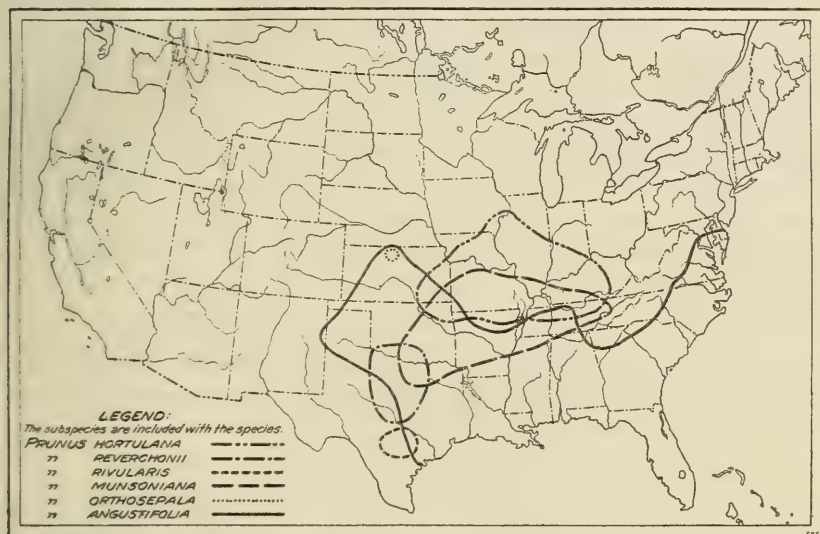


FIG. 2.—Outline map of the United States, showing the distribution of native American species of *Prunus*: *Hortulana*, *reverchonii*, *rivularis*, *munsoniana*, *orthosepala*, and *angustifolia*.

fruiting qualities commend it as a stock where sufficiently hardy, as well as for a fruit-producing tree. The Crimson Beauty, Cumberland, Garfield, Golden Beauty, Kanawha, Leptune, Moreman, Reed, and Wayland varieties belong to this species. Among these varieties Golden Beauty is supposed to have been found wild far beyond the natural range of the species in the Southwest. It was introduced in 1874 by Gilbert Onderdonk, of Nursery, Tex. Mr. Onderdonk writes the following under date of February 1, 1911:

The German whose name I have lost ran off from Gonzales County to the then Indian frontier in the region of Fort Belknap. He did so to avoid conscription into the Confederate Army. I can have no idea that he went up into Oklahoma. There was then exemption from conscription in the Indian frontier counties. When the war was over he returned to Gonzales County, bringing with him cuttings of a plum that he called "Late Yellow Chickasaw," and said that he found it wild not far from Fort Belknap. That is all we know about its origin.

"Fort Belknap," now known as Belknap, is on the Brazos River, in Young County, northern Texas. Another variety, material of which has not been seen but which is referred to this group by Waugh (76, p. 181), is reported to have been found by Dan Irby, of Texas, "growing on the grounds of an old Indian settlement in his vicinity." Crimson Beauty, likewise reported to be of Texas origin, probably came from cultivated material. The introducer, A. L. Bruce, writes that it came from trees in Grayson County, growing in ground "being used as a home garden." The variety Captain was introduced about 1892 by A. M. Ramsey & Son, of Austin, Tex., under the name Columbia. Mr. Ramsey obtained it from J. M. Shell, of Georgetown, Tex., and Mr. Shell writes that he in turn received the variety from Mr. Berckmans, of Augusta, Ga., as Cumberland, and sold it as such. It is evident that the name Columbia originated by an error either in writing or reading the label intended for Cumberland. Later the name Columbia was changed to Captain to avoid confusion with a *domestica* variety. While perhaps it may be difficult to furnish definite proof, it is nevertheless extremely probable that these varieties were all originally carried to Texas from the region of the known natural range of the species, either by the Indians or by the early settlers.

PRUNUS HORTULANA HYBRIDS.

Among the cultivated varieties are a few supposed to represent hybrids of *Prunus hortulana* with *P. triflora*, *P. americana*, *P. munsoniana*, and *P. hortulana mineri*.

PRUNUS HORTULANA MINERI Bailey.

Prunus hortulana mineri Bailey, 1892, N. Y. Cornell Agr. Exp. Sta. Bul. 38, p. 23.

A form differing in botanical characters but little from the species. The bark of the trunk in mature trees shows a slight approach to the scaly character of that of *Prunus americana*. The branches are perhaps somewhat more rigid than in the species and the foliage is a darker green. This form blooms a few days earlier and the fruit also ripens earlier. It is, however, impossible to distinguish *mineri* from the species in herbarium material.

The "Miner group" is a group well recognized by pomologists, but careful study both in the herbarium and in the field fails to reveal any distinctive characters other than as indicated above. It is usually contrasted by pomologists with the "Wild Goose group," *Prunus munsoniana*, or with *P. americana*, but not with the "Wayland group," *P. hortulana*, to which it is clearly most closely related. The varieties referred to this form have mostly originated under cultivation and would therefore not be expected to show the intergradation with the species that is found in a number of specimens from a

wild state, yet a study of several of the varieties referred to this group by pomologists reveals no botanical character of consequence. The suggestion sometimes made that these varieties are hybrids of *Prunus hortulana* with *P. americana* is without foundation and has probably arisen from a misunderstanding of the specific differences.

While *Prunus hortulana* is one of the most recent to receive botanical recognition, this form of the species enjoys the distinction of being apparently the first in which a horticultural variety has been given a name in a publication. This naming of a variety is a noteworthy event in the development of American plums, and what is known concerning the history of this variety has been related earlier in this discussion. If Dodd, who is credited as being the one who planted seed from which the Miner came, really had two lots of plum seeds, as may perhaps be inferred from Mr. Giddings's account previously quoted, it is not clear which was the origin of the Miner or whether it was the one obtained from the Horseshoe Bend of Tallapoosa River. This locality is in the northern part of Tallapoosa County, Ala., and is about 150 miles south of the known range of the species.

PRUNUS HORTULANA MINERI HYBRIDS.

The *mineri* form of *Prunus hortulana* is supposed to have been hybridized with *Prunus americana* (Pl. XIII, fig. 6, Surprise; figs. 7, 8, Hammer), *P. munsoniana*, and *P. pumila*.

PRUNUS REVERCHONII Sargent.

(Hog plum.)

Prunus reverchonii Sarg., 1911, Trees and Shrubs, v. 2, pt. 3, p. 158.

Prunus pygma Munson, 1889, in Amer. Gard. v. 10, no. 5, p. 175. (Not *P. pygmaea* Willd., 1796.)

Leaves lanceolate to ovate-lanceolate and acuminate (Pl. III, fig. 2), usually strongly conduplicate or troughlike and folding at the base when pressed, mostly 5 to 7 cm. long, 2 to 3.5 cm. broad, or those of the young shoots sometimes 9.5 cm. long and 4.5 cm. broad, rounded or narrowed at the base and acute at the apex, the margin glandular serrate, in age the glands appearing as callous points or falling away and leaving the serrations rounded, green and glabrous above, pale green and pubescent with scattered hairs below, or sometimes rather densely pubescent when young, the pubescence sometimes slightly tufted in the axils of the lateral veins; petioles 7 to 12 mm. long, slightly pubescent along the upper surface and usually with two to four glands near the apex; stipules linear, glandular along the margin. Flowers appearing from the last of March to the middle of April, with or before the leaves, in umbels of 2 to 4 or rarely more, about 10 mm. broad; pedicels 6 to 9 mm. long, glabrous;

calyx campanulate, sparingly hairy on the outer surface, the tube about 2 mm. long, the lobes oblong or ovate-oblong and obtuse, 1.5 mm. long, the margin glandular, usually rather strongly pubescent within, at least toward the base, apparently erect or spreading at anthesis; petals obovate to oblong-obovate, 4 to 6 mm. long, 2.5 to 3 mm. broad, narrowed toward the base or sometimes more abruptly contracted to a claw, entire or erose toward the apex. Fruit ripening in August or early September, globose or subglobose, 1.5 to 2 cm. in diameter, usually yellow overlaid with crimson on one side or sometimes golden yellow with whitish dots, rarely entirely red, bloom thin or wanting, flesh yellow and rather firm, quality usually poor, but occasionally good; stone oblong (Pl. X, figs. 13 to 22), 11 by 7 by 5 mm. to 13.5 by 10 by 7 mm., pointed at each end or sometimes somewhat truncate at the base and rounded, but with an abrupt point at the apex, irregularly grooved and ridged near the ventral edge, indistinctly grooved along the dorsal edge, the surface smooth or obscurely reticulate.

Prunus reverchonii is a shrub usually 2 to 6 feet high; the bark of the stem is gray, while that of the young twigs is chestnut or dull reddish chestnut, turning to a dull gray the second year, or rarely becoming grayish the first year; lenticels small, round, and lighter colored.

The species (fig. 2) forms very dense thickets on the black upland soils and in the rich bottom lands along streams from Limestone Gap and the vicinity of the False Washita in southern Oklahoma southward to the Colorado in Texas. It probably does not occur east of the ninety-sixth meridian, but its western limits are not known. It has been collected along the Little Wichita, in Clay County, on hills near the Concho River, and in Lampasas County. Foliage closely resembling this has also been collected in the vicinity of Fort Davis, in western Texas, but without flowers or fruit the specimen can not be definitely referred to this species.

Prunus reverchonii is closely related to *P. rivularis* and is sometimes difficult to distinguish in the herbarium from that species. Additional material and study in the field may require it to be ranked as a subspecies of the latter. The apparent differences are its more branching and less slender stems, trough-shaped leaves, later ripening fruit, and more pointed stone. It is generally regarded as of little value horticulturally, but its adaptability to limestone soils and ability to withstand severe drought may make it of value as a dwarf stock, if its habit of suckering is not too great an objection. The small stone and the fact that occasional thickets are found producing fruit of fair quality suggest also that the fruit should not be entirely neglected. One thicket on the Little Wichita River, west of Henrietta, Tex.,

produced fruit identical in color with the variety Golden Beauty of *Prunus hortulana*. This fruit was of good quality and was remarkable in having the smallest stone of any specimen found, being about 9 by 6 by 5 mm. The stone is slightly less pointed than usual, but no other distinguishing differences were found. The species is used locally in Texas for jellies and preserves.

PRUNUS REVERCHONII HYBRID.

A form found near Henrietta, Tex., and referred to under *Prunus mexicana*, is apparently a hybrid. It may be characterized as follows: Leaves ovate or sometimes nearly oval and acuminate, mostly 4.5 to 7 cm. long, 2.5 to 3.5 cm. broad, gradually narrowed at the base, acuminate toward the apex, sometimes abruptly so, dull green and glabrous or nearly so above, pale and sparingly soft-pubescent below, the margins serrate, the serrations acute or often somewhat obtuse, sometimes glandular, at least when young; petioles 7 to 10 mm. long, hairy, and usually with one or more glands toward the apex. Flowers appearing before the leaves, about 12 mm. broad, in umbels of 2 to 4, umbels short stalked, the stalk sometimes 3 mm. long; pedicels slender and glabrous, 8 to 10 mm. long; calyx rather narrowly campanulate, glabrous or sparingly and obscurely pubescent, the tube about 3 mm. long, the lobes ovate, 2 mm. long, glandular, and hairy within; petals oblong-orbicular and narrowed to a claw, about 5 mm. long.

The hybrid is a small tree with the young twigs chestnut colored, later becoming grayish; lenticels oval, not very prominent, and the branches apparently without thorns. In texture of leaf it resembles *Prunus mexicana*, but the shape of the leaf suggests that of *P. reverchonii*, and it resembles the latter also in the size of flowers and in its calyx characters. One form, apparently a hybrid, also originating near Henrietta, was for a time under cultivation in the nursery of A. M. Ramsey, at Austin, Tex., and by some other firms under the name of Ward's October Red. Mr. Ramsey grew a number of seedlings and these showed great variation; none of them, however, produced fruit of merit, and the trees were destroyed in 1910.

PRUNUS RIVULARIS Scheele.

(Creek plum.)

Prunus rivularis Scheele, 1848, in *Linnaea*, Bd. 21, Heft 5, p. 594.

Prunus texana Scheele, 1848, in *Linnaea*, Bd. 21, Heft 5, p. 593. (Not Dietrich, 1843.)

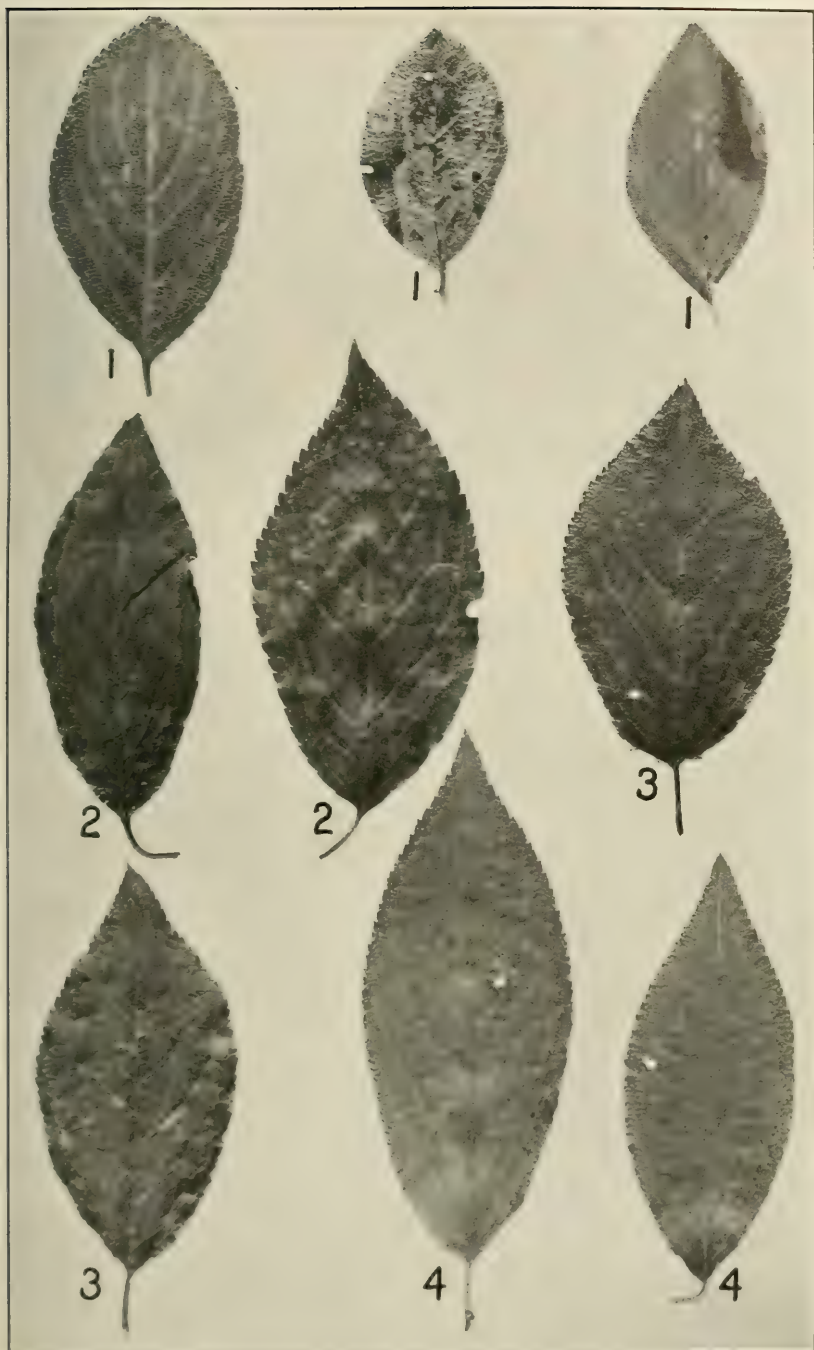
Leaves ovate to oblong-ovate (Pl. III, fig. 3) or sometimes slightly obovate, rounded at the base, usually short acuminate, 6 to 7.5 cm. long, 2 to 4 cm. broad, usually not folding at the base when

pressed, glandular serrate, the glands remaining as callous points, glabrous and green above, pale green and pubescent with scattered hairs below or rather densely pubescent when young, the pubescence rarely or not at all tufted in the axils of the lateral veins; petioles 10 to 12 mm. long, glandless or with one or two glands near the apex, pubescent along the upper edge; stipules linear or lobed, glandular. Flowers appearing in February or March, with or before the leaves, in umbels of 2 to 4 or rarely 5, about 9 or 10 mm. broad; pedicels 6 to 8 mm. long, slender, glabrous; calyx campanulate, the tube glabrous, about 2 mm. long, the lobes as long as the tube and ovate or oblong-ovate, usually pointed at the apex, glandular, obscurely pubescent on the outside, pubescent on the inner surface toward the base, and reflexed in age; petals 4 to 4.5 mm. or rarely 5 mm. long, 2.5 mm. broad, obovate-orbicular, or rarely oblong-obovate, narrowed to a very short claw. Fruit ripening in June, subglobose, about 15 mm. in diameter, red with a light bloom; stone oval to nearly globose (Pl. X, figs. 23 and 24), 9 to 12 mm. long, 7 to 9 mm. broad, 6 to 7 mm. thick, rounded or slightly pointed at the apex and rounded or obliquely truncate at the base, irregularly grooved along the vertical edge, the dorsal edge inconspicuously grooved or sometimes smooth, surface obscurely rugose.

The species is a shrub 3 to 8 feet high with slender stems, forming open thickets. The bark of the stems is gray, that of the young twigs grayish or rarely somewhat reddish or pale chestnut in color, obscurely marked with oval lenticels; winter buds small.

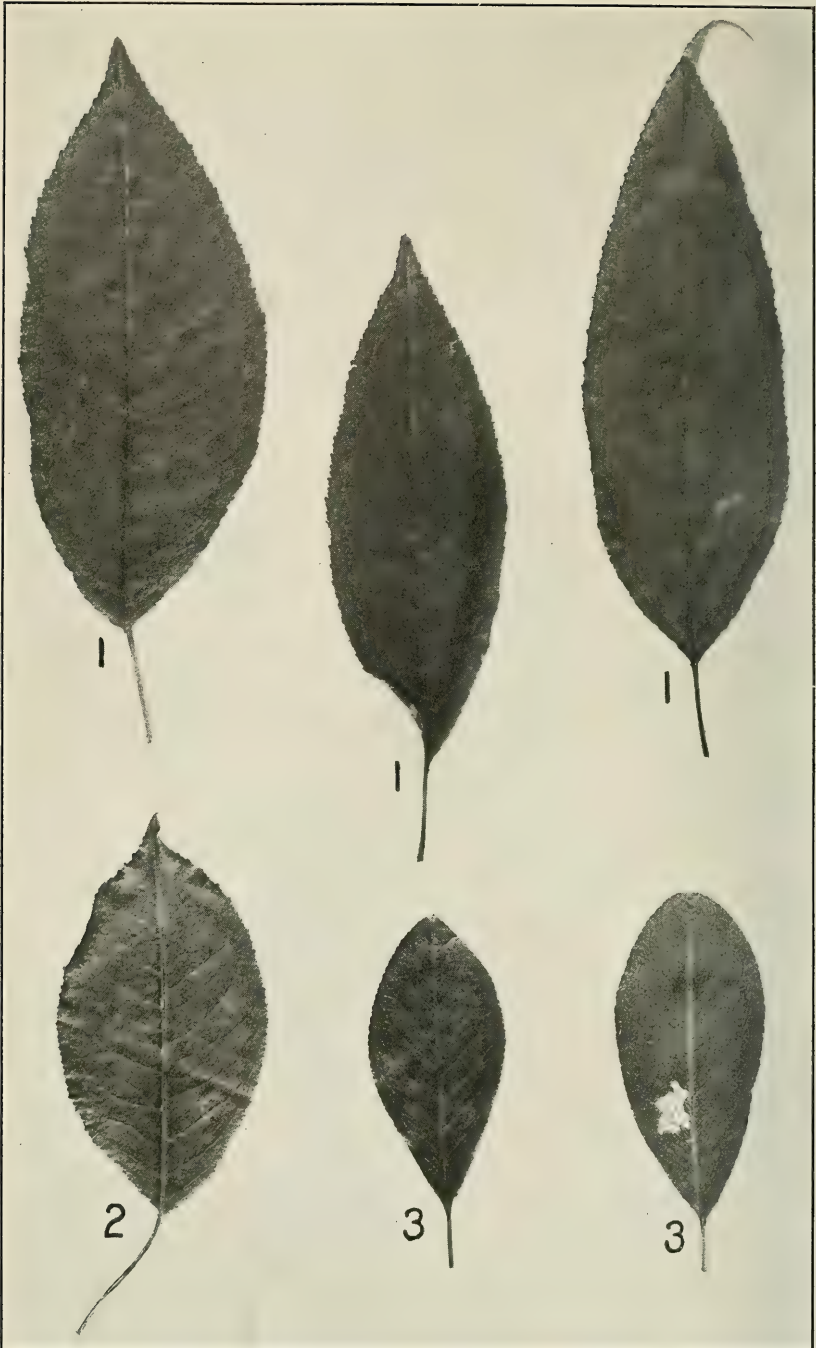
Prunus rivularis occurs (fig. 2) in bottom lands along streams in Texas from the Rio Blanco, in Hays County, to San Antonio. It is apparently not very abundant.

The species was originally described from a specimen collected by Lindheimer, but neither the date nor locality are cited by Scheele. Among the seven specimens in the herbarium of the Missouri Botanical Garden collected by Lindheimer, one (No. 274, 1846) has a label with the same data that are given by Scheele and is apparently a duplicate of the type. On the same sheet is a package of stones labeled "New Braunfels, Texas, 1846, Lindheimer," and there can be little doubt that this is the type locality. *Prunus texana* was described from material collected by Roemer at New Braunfels, and a flowering specimen of his in the herbarium of the Missouri Botanical Garden, "*Prunus texana* Scheele," bears the legend "Scheele misit" and is evidently part of the type material. It does not differ from *P. rivularis*. The Indians, according to Lindheimer, gathered these plums and cooked them with honey, but the fruit is small, poor in quality, and the species apparently has little value in horticulture.



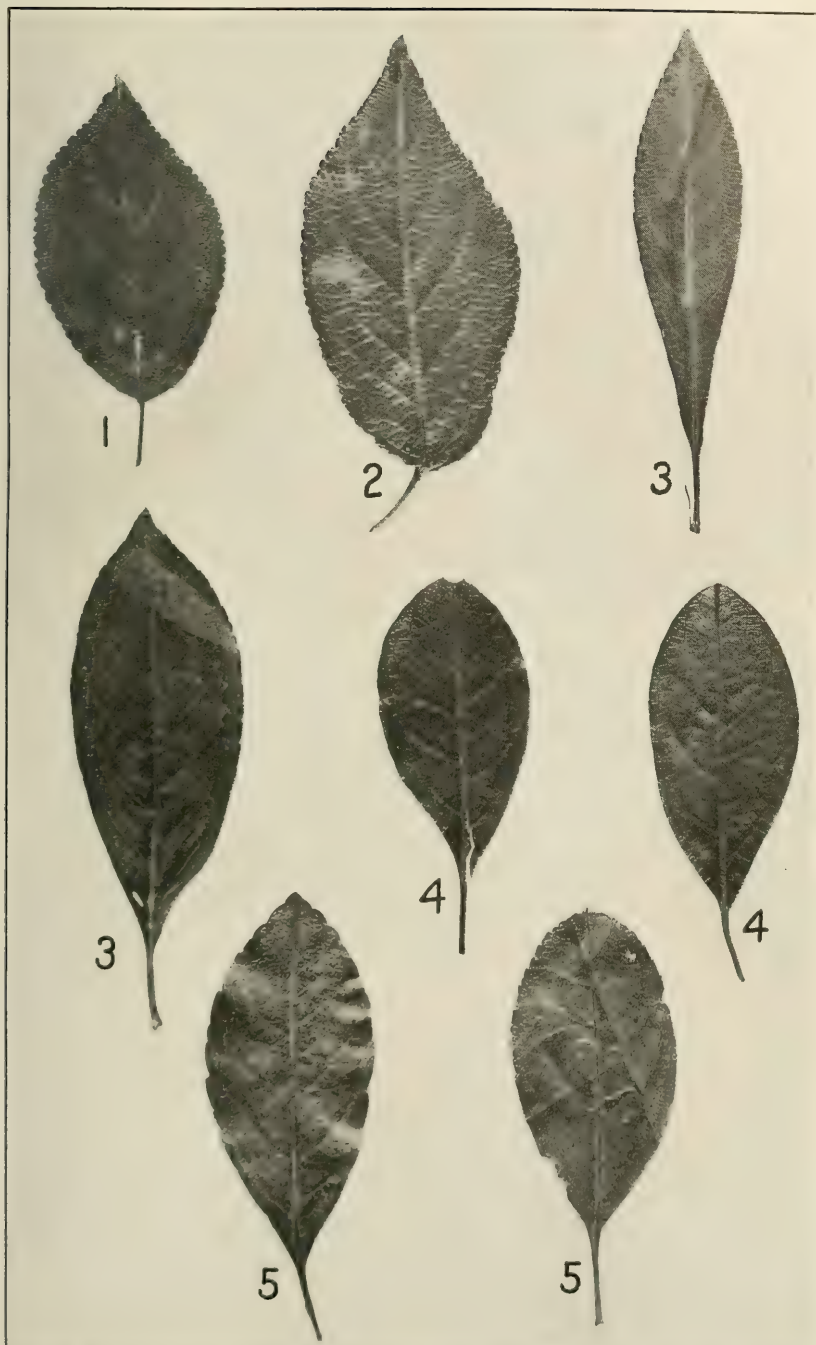
LEAVES OF THE NATIVE AMERICAN SPECIES OF PRUNUS.—V: 1, PRUNUS MARITIMA; 2, P. ALLEGHANIENSIS; 3, P. ALLEGHANIENSIS DAVISII; 4, P. UMBELLATA.

(Natural size.)



LEAVES OF THE NATIVE AMERICAN SPECIES OF PRUNUS.—VI: 1, *PRUNUS PENNSYLVANICA*;
2, *P. PENNSYLVANICA CORYMBOSA*; 3, *P. EMARGINATA*.

(Natural size.)



LEAVES OF THE NATIVE AMERICAN SPECIES OF PRUNUS.—VII: 1, *PRUNUS GRACILIS*; 2, *P. VENULOSA*; 3, *P. PUMILA*; 4, *P. CUNEATA*; 5, *P. BESSEYI*.

(Natural size.)

PRUNUS MUNSONIANA Wight and Hedrick.

Prunus munsoniana Wight and Hedrick, 1911, in Hedrick, Plums of New York, p. 88.

Prunus hortulana Bailey, in part, 1892, N. Y. Cornell Agr. Exp. Sta. Bul. 38, p. 16.

Prunus hortulana Waugh, 1899, in Vt. Agr. Exp. Sta. 12th Ann. Rpt., p. 195. (Not

P. hortulana Bailey, 1892, in Gard. and Forest, v. 5, p. 90.)

Leaves lanceolate to oblong-lanceolate (Pl. IV, fig. 1), or sometimes broadly oblong-lanceolate, usually 6 to 10 cm. long, 2.5 to 4 cm. broad, rounded at the base, acute or occasionally somewhat acuminate at the apex, the margins rather finely glandular serrate, bright green and lustrous on the upper surface, the lower surface paler and rather sparingly pubescent along the midrib and lateral veins, the pubescence often tufted in the axils of the veins, the surface rarely pubescent except when young, and even more rarely entirely glabrous; petioles slender, 1.5 to 2 cm. long, with a pubescent line along the upper side, usually biglandular near the base of the leaf blade; stipules linear, glandular serrate. Flowers 12 to 15 mm. in diameter, appearing from the last of March before the leaves in the South to the last of May and with the leaves in the North (latitude of New York), in 2 to 4 flowered, umbellike clusters; pedicels slender, glabrous, 10 to 12 mm. long; calyx tube campanulate, glabrous, obscurely nerved, about 3 mm. long, the lobes ovate-oblong to oblong and obtuse at the apex, as long as the tube, glandular on the margin, glabrous or rarely sparingly pubescent on the outer surface, pubescent on the inner surface near the base, or the pubescence rarely extending above the middle, the margin usually ciliate toward the base; petals 6 to 7 mm. long, obovate or oblong-obovate, abruptly contracted into a short claw, the margin entire or sparingly erose. Fruit globose or oval, usually bright red with whitish dots and sometimes yellowish markings and a light bloom, ripening in July and August; stone oval (Pl. XI, figs. 1 to 16), varying from 9 by 13 mm. in the wild state to 12 by 20 mm., or even 14 by 20 mm. in some of the cultivated varieties, usually truncate or obliquely truncate at the base, pointed at the apex, grooved on the dorsal edge, thick margined and rather conspicuously grooved on the ventral, the surface irregularly roughened, though sometimes rather inconspicuously so.

The species forms dense thickets in its native habitat with the older central specimens sometimes attaining a height of 20 or more feet and gradually diminishing in height to the edge of the thicket. When budded and grown in the orchard it forms a well-defined trunk and attains a height of 25 feet or more. The branches are little or not at all spinescent; the bark of the stem in young specimens is reddish or chestnut brown and usually rather smooth, becoming scaly and losing its reddish color with age; that of the young twigs is usually chestnut brown.

Prunus munsoniana is found (fig. 2) in rather rich soils and ranges from central Tennessee and southwestern Kentucky through northern Mississippi, northern and central Arkansas, central Missouri, and southeastern Kansas to the valley of the Little Wichita River, in northern Texas.

Although *Prunus munsoniana* is the last species prominent in horticulture to receive specific botanical recognition, it embraces horticultural varieties among the earliest, if not the earliest, of any American species to be described. It embraces one or more varieties that are probably the best known and most widely disseminated among those of native origin. There will perhaps be some question among horticulturists concerning the reference of the variety Wild Goose to this species, but a most critical study of specimens of this variety from many localities fails to reveal a single botanical character in which it differs from others. The varieties Arkansas, Clifford, Mrs. Cleveland, Cooper, Downing, Choptank, Davis, Drouth King, Hollister, Hughes, Jewell, Macedonia, Miles, Milton, Newman, Nimon, Ohio, Osage, Poole Pride, Pottawattamie, Robinson, Texas Belle, Thousand and One, Whitaker, Wild Goose, Wonder, and Wooten, all belong to this species. Nearly all of the varieties have until recently been referred to *Prunus angustifolia*, from which the present species is distinguished by its more vigorous and hardy character, larger and more pointed leaves, larger flowers, and glandular calyx lobes.

PRUNUS MUNSONIANA HYBRIDS.

The originators of new varieties have made many hybrids of *Prunus munsoniana* with other species. Crosses are supposed to have been made with *P. americana*, *P. angustifolia* *varians*, *P. cerasifera*, (Pl. XIII, figs. 11 and 12, Marianna), *P. hortulana*, *P. hortulana mineri*, *P. triflora*, *P. simonii* [*(munsoniana* $\times$ *triflora*) $\times$ (*triflora* $\times$ *simonii*)] and with *Amygdalus persica*.

PRUNUS ANGUSTIFOLIA Marsh.

(Chickasaw plum.)

Prunus angustifolia Marsh., 1785, Arb. Amer., p. 111.

Prunus chicensis Michx., 1803, Fl. Bor. Amer., t. 1, p. 284.

Prunus stenophyllus Raf., 1817, Fl. Ludov., p. 98.

Cerasus chicensis Ser., 1825, in DC. Prodr., pars. 2, p. 538.

Prunus chicensis angustifolia Roem., 1847, Fam. Nat. Sym. Mon., fasc. 3, p. 58.

Leaves (Pl. IV, fig. 2) lanceolate or oval-lanceolate, 2 to 5 cm. long, 1 to 2 cm. broad, usually strongly conduplicate, narrowed or rarely rounded toward the base, acute at the apex or obtuse when they first unfold, the margin finely glandular serrate, glabrous and lustrous

green above, pale below and sparingly pubescent along the mid-vein toward the base, or sometimes entirely glabrous; petioles 5 to 10 mm. long, usually reddish and pubescent along the upper edge, glandular near the apex or eglandular; stipules linear lanceolate, glandular serrate. Flowers 8 or 9 mm. broad, appearing before the leaves from the middle of February in northern Florida to the first of April in Virginia, in umbels of 2 to 4; pedicels 3 to 6 mm. long, glabrous; calyx tube obconic, glabrous, 2 to 2.5 mm. long, the ovate, obtuse lobes shorter than the tube, glabrous on the outer surface, glabrous within, except near the base, or inner surface sometimes sparingly pubescent, the margin ciliate, eglandular; petals about 4 mm. long, ovate-orbicular or obovate-orbicular, abruptly contracted to a claw. Fruit ripening from the first of June in the South to the middle of July in the northern portion of its range, subglobose, skin thin, flesh yellow, frequently of very good quality; stone oval (Pl. XI, figs 17 and 18), 11 or 12 mm. long, about 10 mm. broad, about 7 mm. thick, obtuse at the base, obtuse or somewhat pointed at the apex, rounded on the ventral edge and usually grooved on either side, grooved along the dorsal edge.

The tree is small, reaching a maximum height of about 10 feet, or more often only a shrub forming dense thickets; the bark of the trunk in the younger stems is dark reddish brown, rather smooth or becoming slightly furrowed in age.

The species ranges (fig. 2) from the Eastern Shore of Maryland and southern Delaware southward in the sandy soils of the coast region to northern and central Florida and westward through Mississippi, Louisiana, and southern Arkansas to central Texas. Specimens referable to this species have also been collected in western Kentucky and Tennessee, but its occurrence in the former, at least as an indigenous species, is to be doubted.

Prunus angustifolia was described by Marshall, but no locality was given other than "the Southern States." The specimen in the Michaux herbarium in the Muséum d'Histoire Naturelle labeled *Prunus chicasa* is not this species and has not been definitely identified. The description, however, can refer to no other plant. Rafinesque's *Prunus stenophyllus* described as being from "near Washita," in southern Arkansas, can not be other than this species. Rafinesque, who evidently did not see specimens, based his species on *Cerasus canadensis* Robin (65, p. 495; not Miller, 1768).

Prunus angustifolia is much less important horticulturally than either of its subspecies, and among the cultivated varieties studied few, among which are Ogeeche and Caddo Chief, can be referred to it. The fruit is small, and it is probably less hardy than either of its subspecies.

PRUNUS ANGUSTIFOLIA HYBRIDS.

The early ripening of the fruit of *Prunus angustifolia* has caused it to be used in hybridizing with *P. triflora* (Pl. XIII, fig. 13, Six Weeks) with which it crosses very readily, and it is supposed also to be one of the species used in producing the variety Chicrigland. This is said to be a combination of *P. angustifolia*, *P. reverchonii*, and *P. texana* (*P. glandulosa* (Hook.) Torr. and Gray).

PRUNUS ANGUSTIFOLIA WATSONI (Sargent) Waugh.

(Sand plum.)

Prunus watsoni Sarg., 1894, in Gard. and Forest, v. 7, p. 134, f. 25.

Prunus angustifolia watsoni Waugh, 1899, in Vt. Agr. Exp. Sta., 12th Ann. Rpt., 239.

Leaves oval or oblong-oval, 3 to 4.5 cm. long, 12 to 18 mm. broad, gradually narrowed toward the base, usually acute at the apex, sometimes abruptly so, lustrous above, pale and glabrous below or sometimes a few scattered hairs along the midrib toward the base, the margin finely crenate and glandular; petioles slender, 6 to 18 mm. long, glabrous, or sometimes pubescent along the upper edge. Flowers appearing in Kansas from the last of March to about April 20, sometimes with red anthers, otherwise not differing from the species. Fruit very similar to the species, but ripening from the first of August to the first of October, or in the Panhandle region early in July; stone oval or rarely obovoid, about 13 or 14 mm. long, 9 mm. broad, 7 mm. thick, truncate or oblique at the base, rounded or pointed at the apex, variously grooved on either side of the ventral edge or the grooves very obscure but without a winglike margin, grooved along the dorsal edge, prolonged at the base when obovoid.

Prunus angustifolia watsoni is usually a shrub 3 to 6 feet high with rather stiff branches, these often furnished with spinescent branchlets.

The subspecies was originally described from garden specimens grown from seed sent from Ellis, Kans., by Dr. Louis Watson. It ranges from northeastern Kansas southwestward through Oklahoma and the Panhandle region of Texas to the vicinity of Nara Visa, Quay County, in northeastern New Mexico. Its eastern boundary is not well defined, but no specimens have been observed east of a line drawn from the northeastern part of Kansas southwestward to the junction of the North Fork of Red River with the main stream, yet it doubtless occurs somewhat farther east. It does not appear to have been collected much west of Ellis and Seward Counties, in Kansas. It has several times been reported from southeastern Nebraska, but no specimens are to be found in the larger herbaria from that region, and it probably occurs in Nebraska only under cultivation.

Prunus angustifolia watsoni is very difficult to distinguish from the species in the herbarium, but the leaves appear to be less pointed, slightly less minutely serrate, and the serrations less deep in proportion to their length, with the glands less often near the center of the teeth but frequently even in the lowest part of the indentation. In the field, the form usually appears even more shrubby, the branches more zigzag, and the fruit usually ripens later. A few specimens from southwestern Kansas and one from New Mexico are unusually pubescent, but they do not differ otherwise.

The fruit is often gathered in considerable quantities in many localities and is sometimes sold in the markets. This form is also sometimes grown in small orchards in Kansas. Among the named varieties which appear to belong to the subspecies, Purple Panhandle, Red Panhandle, Yellow Panhandle, and Quitique have come from the Panhandle region of Texas. Other varieties are Strawberry and Welcome. These plums are said to appear promising in their native region, but they proved disappointing when brought to Austin, Tex., where some of them were introduced to the trade. Nevertheless, the form should not be lost sight of in any comprehensive effort to improve the native species.

PRUNUS ANGUSTIFOLIA WATSONI HYBRIDS.

There is little doubt that the form known as the Utah hybrid, $\times$ *Prunus utahensis* has this subspecies for one of its parents. It is also supposed to hybridize with *P. americana*, and these hybrids are discussed under *P. besseyi* and *P. orthosepala*, respectively.

PRUNUS ANGUSTIFOLIA VARIANS Wight and Hedrick.

Prunus angustifolia varians Wight and Hedrick, in Hedrick, 1911, The Plums of New York, p. 87.

Leaves oblong-oval, oval-lanceolate, or rarely slightly obovate-lanceolate, mostly 3.5 to 6 cm. long, 2 to 2.5 cm. broad, gradually narrowed at the base, acute at the apex, the margin very minutely glandular serrate, glabrous and somewhat lustrous above, slightly pale, glabrous or sparingly hairy along the midrib and in the axils of the lateral veins on the lower surface; the slender petioles usually reddish, 10 to 15 mm. long, pubescent along the upper side, eglandular or sometimes with one or two glands at the apex; stipules 3 to 4 mm. long, linear, and glandular dentate. Flowers, appearing from early in March and before the leaves in the South to the middle of April and with the leaves in the North, in dried specimens 10 to 12 mm. broad; pedicels 7 to 9 mm. long, glabrous; calyx campanulate, the tube 2 to 2.5 mm. long, glabrous, the lobes usually shorter than the tube, oblong and obtuse, glabrous on the outer surface, glabrous or sometimes sparingly pubescent on the inner, the margin ciliate, eglandular;

petals about 5 mm. long, obovate and gradually narrowed toward the base, erose or entire toward the apex. Fruit mostly ripening in June in its native region, globose or subglobose, varying from red to yellow, usually with a light bloom; stone 13 to 16 mm. long, 9 to 12 mm. broad, turgid, ovoid to elliptic oblong, obscurely pointed at the apex or sometimes slightly obtuse, truncate or obliquely truncate at the base, grooved on the dorsal edge, the ventral edge with a narrow, thickened, and slightly grooved wing, the surface irregularly roughened.

In its native state *Prunus angustifolia varians* forms dense thickets, as does the species, the larger specimens attaining a height of about 11 feet. When budded and grown in the orchard it assumes the form of a small tree with well-defined trunk and spreading branches, sometimes armed with rather slender spinescent branchlets. It is distinguished from the species by its usually more robust habit, by having the young twigs less reddish and approaching chestnut brown in color, by rather longer leaves and longer pediceled flowers, and by the stone usually being more pointed at the apex.

Prunus angustifolia varians usually grows in more fertile soil than the species. It occurs locally from southern Oklahoma through eastern Texas southward, possibly to the Colorado River, and probably westward nearly to the Panhandle region. As yet, however, its distribution is not well defined.

Prunus angustifolia varians embraces nearly all of the early-ripening horticultural varieties previously referred to *P. angustifolia*, and its fruit appears to be superior to that of the species. Among the varieties typical of the form may be mentioned African, Clark, Cluck, Coletta, Emerson, Fawn, Mason, Piram, and Yellow Transparent.

PRUNUS ANGUSTIFOLIA VARIANS HYBRIDS.

The subspecies *Prunus angustifolia varians* has apparently been crossed with *P. munsoniana* and *P. triflora*, and the variety Marianna (Pl. XIII, figs. 11 and 12) may represent a hybrid either of this form or of *P. angustifolia* with *P. cerasifera*. Since its introduction the parentage of the Marianna has remained in doubt, and even now its origin is not clear. The history of the variety is given by G. Onderdonk (58, p. 28), the well-known nurseryman of southern Texas, as follows:

It was an accidental seedling on the grounds of Mr. C. G. Fitze, at Marianna, Polk County, Tex. Cuttings were furnished Mr. C. N. Ely in 1877. He named it Marianna, after the locality of its origin, and introduced it to the public.

Mr. Ely lived at Smith Point, Tex., and introduced the variety in 1884 (5, p. 213). It has sometimes been considered a hybrid of *Prunus cerasifera* with the Wild Goose, *P. munsoniana*, and these species may

represent its parentage. Nevertheless, the close resemblance to *P. angustifolia* in some of the flower characters, particularly the calyx lobes, which are entirely without glands, suggests either that species or *P. angustifolia varians* as one of the parents. A hybrid of the Wild Goose and *P. cerasifera* might also be expected to produce a form with larger and longer leaves than the Marianna.

PRUNUS ORTHOSEPALA Koehne.

Prunus orthosepala Koehne, 1893, Deut. Dendrol., p. 311.

Leaves (Pl. IV, fig. 3) varying from oblong-lanceolate to obovate-lanceolate, mostly 4 to 6 cm. long, 1 to 2.5 cm. broad, narrowed at the base and acute or acuminate at the apex, the margins serrate with acute or more often slightly obtuse teeth, these occasionally tipped with a callous point, bright green, glabrous, and somewhat lustrous on the upper surface, pale green and glabrous or with a few scattered hairs along the rather prominent midvein; petioles 8 to 15 mm. long, puberulous along the upper surface and eglandular or with one or two glands near the upper end. Flowers appearing the last of April or early in May, 10 to 14 mm. broad in 3 to 4 flowered umbels; pedicels 3 to 5 mm. long, glabrous; calyx tube campanulate, 2 to 2.5 mm. long, glabrous, the oblong obtuse lobes about 2 mm. long, glabrous or nearly so on the outer surface, ciliate on the margin and sparingly pubescent within, dentate or entire at the apex; petals oblong-obovate, 4 to 5 mm. long, 2.5 to 3 mm. broad, entire or erose at the apex, white, or in age with a distinct pinkish tinge. Fruit ripening at the Arnold Arboretum about the middle of September, globose, about 2.5 cm. in diameter, red with white dots, and covered with bloom; stone oval (Pl. XIII, fig. 1), about 15 mm. long, 12 mm. broad, slightly pointed at the base and rounded at the apex, rather irregularly grooved near the ventral suture, grooved along the dorsal edge, and the surface obscurely rugose.

Prunus orthosepala, as it grows in the few American arboreta where it is cultivated, is a much-branched, spreading shrub about 5 feet high. The bark of the stem and larger branches separates in platelike scales; that of the smaller branches is dark brown in color, marked with lighter colored lenticels, while that of the young branchlets is chestnut colored.

The history of this species, as given by Sargent (67), is as follows:

In June, 1880, Dr. George Engelmann, of St. Louis, sent to the Arnold Arboretum a package of seeds marked "*Prunus* sp., southern Texas." Plants were raised from these seeds, and in 1888, or earlier, they flowered and produced fruit which showed that they belonged to a distinct and probably undescribed species. A name, however, was not proposed for it, and, in 1888 probably, plants or seeds were sent to Herr Späth, of the Rixdorf Nurseries, near Berlin, where this plum was found in flower by Dr. Emil Koehne, who has described it under the name of *Prunus orthosepala*.

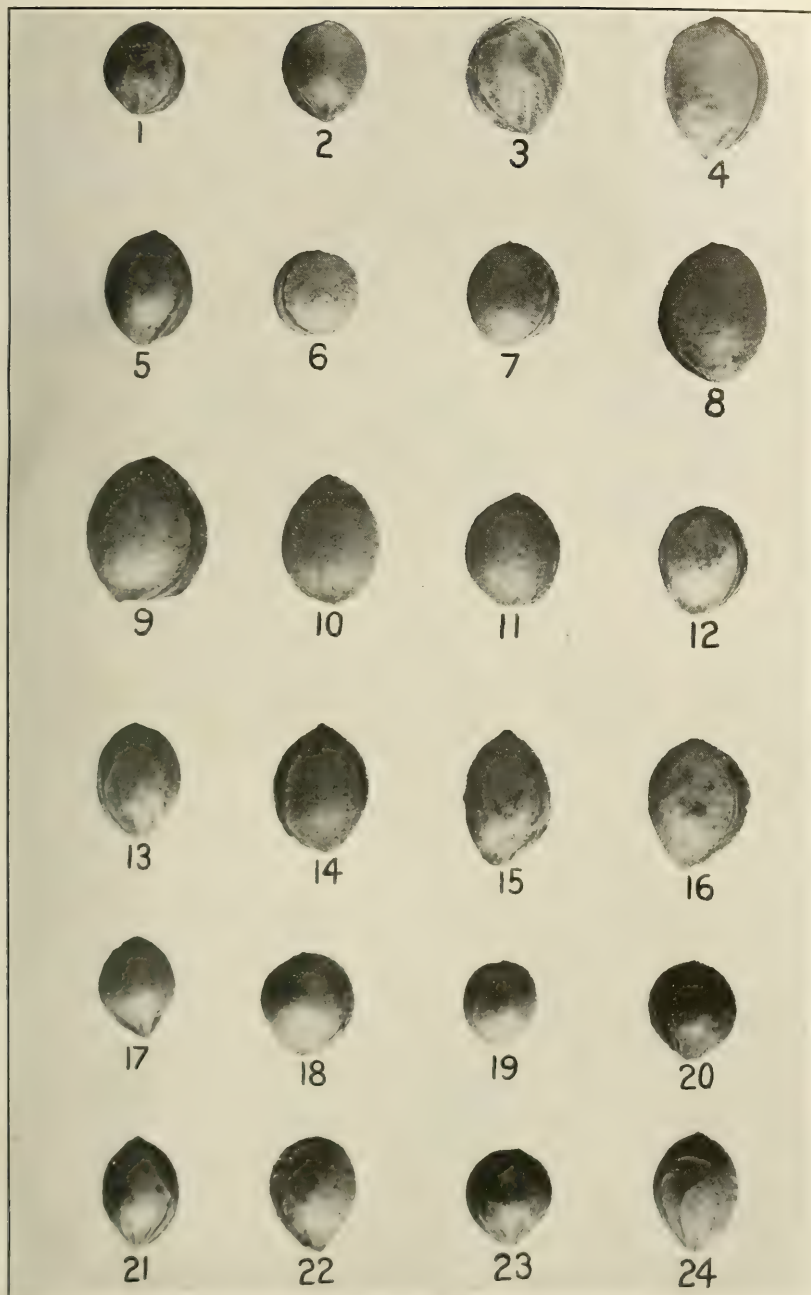
There are no specimens from Texas in any of the American herbaria consulted that can be referred to this species, but seeds of another species, it seems, were received from Dr. Engelmann at the same time, and in 1910 they were with a specimen of *Prunus orthosepala* grown on the grounds and now in the herbarium of the Arnold Arboretum. These seeds represent a species that occurs in Texas, and it is quite possible that they are the ones referred to by Dr. Engelmann and that those of *P. orthosepala* did not come from that State. Still more doubt is cast on the Texas origin by the fact that in the Gray Herbarium of Harvard University, there are several fragmentary specimens of *Prunus* from Ellis, Kans., sent by Dr. Louis Watson to his brother, Sereno Watson. One of these specimens bears the date June 4, 1880; others were sent on August 1, 1881. These fragments consist of leaves and immature fruit. The leaves are very similar in shape to *P. orthosepala*, but vary considerably in the serration of the margin, the teeth of some being much more acute than others. *P. orthosepala* itself shows some variation in this respect, specimens from Dr. Koehne being more sharply serrate than those grown either in the Arnold Arboretum or in the nursery of Mr. J. W. Kerr, near Denton, Md. None of the Kansas specimens have the leaves so sharply serrate as in those from Dr. Koehne, but some of them appear to approach very closely those grown in the arboretum. The seeds, too, of several of them are practically identical with those of *P. orthosepala*, while others are somewhat more oblong. The following is an extract from Dr. Watson's letter describing the trees:

I mail to-day a cigar box containing specimens of plums just gathered—some of them are from Mother Smith's garden from seed. She says I mustn't fail to tell you this. I number them from 1 to 7, thus: (1) 8 or 10 feet high, ripening considerably later than the others; (2) 6 or 8 feet, ripening now; (3) 6 feet, a freestone, ripening now; (4) "sand plum," 2 to 3½ feet, open leaves, ripening now; (5) "sand plum," 2 to 3½ feet, ripe now, with closed leaves (not a good specimen, as it does not show the closed leaf as much as common); (6) 6 feet, ripening; (7) egg-shaped plums of the taller sort, but I have no leaves except a small sprig attached to one.

P. S.—Some bushes of the sand plum bear egg-shaped plums. I have added some specimens as No. 8; also put in some extra ones of the taller kind, whether I numbered them or not I don't know.

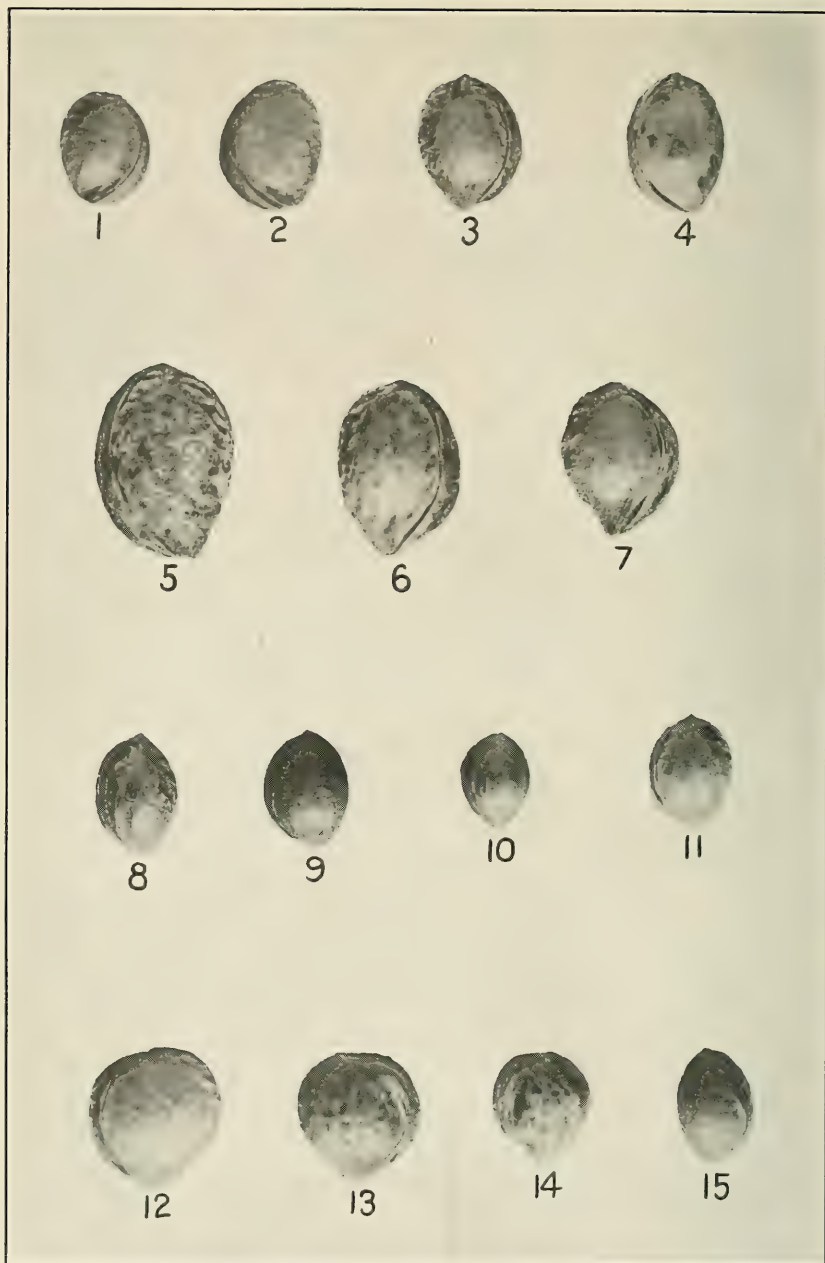
Of these, Nos. 4, 5, 6, and 7 are the sand plum, later described as *Prunus watsoni*, while all the others bear some resemblance in the character of the leaves and seeds to *P. orthosepala*. The specimen sent in June, 1880, is described as a "large yellow plum ripening last of August and later."

A small tree in Highland Park, Rochester, N. Y., which came originally from the Arnold Arboretum, is very evidently of the same character as the larger plums described by Dr. Watson, and the seeds were probably obtained at the same time as were those of *Prunus angustifolia watsoni*. This tree bore abundantly in 1911, the fruit



STONES OF THE NATIVE AMERICAN SPECIES OF PRUNUS.—I.

FIGS. 1 to 16.—*Prunus americana*: 1, From a wild tree, Hardystonville, N. J.; 2, from Easton, Pa.; 3, from Leon County, Fla.; 4, from Center Creek, southwestern Missouri; 5, from near Grand Rapids, Mich.; 6, from Terra Alta, W. Va.; 7 and 8, from Big Horn, Wyo.; 9, Hawkeye variety; 10, De Soto; 11, Rollingsstone; 12, Wolf; 13, Ocheeda; 14, Wyant; 15, Wallace; 16, Wragg. FIGS. 17 to 24.—*Prunus mexicana*: 17, From a wild tree at Tulsa, Okla.; 18, from Oklahoma City, Okla.; 19, from Fulton, Ark.; 20, from Alexandria, La.; 21, from Fort Worth, Tex.; 22, from Dallas, Tex.; 23, from Gonzales, Tex.; 24, from San Antonio, Tex. (Natural size.)



STONES OF THE NATIVE AMERICAN SPECIES OF PRUNUS.—II.

FIGS. 1 to 7.—*Prunus nigra*: 1 and 2, From a wild tree near Atlanta, Mich.; 3, from Piscataquis River, Me.; 4, Cheney variety; 5, 6, and 7, Aitkin. FIGS. 8 to 15.—*Prunus subcordata*: 8, From a wild tree, Warner Mountains, Cal.; 9, from Klamath Indian Reservation, Oreg.; 10, from Pine Grove, Klamath County, Oreg.; 11, from Swan Lake Valley, Klamath County, Oreg.; 12, from Klamath Falls, Oreg.; 13 and 14, from Sprague River, Oreg.; 15, from Klamath Indian Reservation, Oreg. (Natural size.)

ripening at the same time and being scarcely distinguishable in color and shape from that of *P. orthosepala*. It is about 3 cm. long and nearly the same in diameter, being slightly larger than the fruit of the latter species and with a longer stone. (Pl. XIII, fig. 2.)

A plum very similar to if not identical with at least some of the above was first brought into cultivation by Abram Laire, a few miles south of Kirwin, in the southern part of Phillips County, Kans. (fig. 2). Mr. Laire was interviewed in September, 1910, and the following account of the variety known as Laire (Pl. XIII, figs. 3 to 5) was obtained. About the year 1878 (Mr. Laire is uncertain whether it may not have been a year or two later than that date) he and his son brought in from a wild state from various localities along Bow Creek a number of young plum trees. Among these trees when they fruited he discovered perhaps half a dozen trees that produced fruit of superior quality, and these were then noticed to have different foliage from either the sand plum or *Prunus americana*. Mr. Laire was, however, unable to rediscover the thicket from which they were obtained, although his son believes them to have been secured from a thicket in a pasture not far distant which had later been destroyed by cattle. E. Bartholomew, of Stockton, Kans., estimated in 1910 that there were at least 100,000 trees of this variety under cultivation in that part of Kansas, but he has never observed it in a wild state.

The variety Laire, as it grows in Kansas, is a larger tree than *Prunus orthosepala*, and the serrations of the leaves are distinctly rounded. The flowers appear identical with those of the latter species, except in the usually, though not always, shorter pedicels and in the length of the calyx lobes, which are slightly shorter, showing in these respects, as in the more rounded serrations of the leaves, a closer approach to the sand plum. The fruit is nearly globose, dark red with a distinct bloom, and ripens in September. The Laire also suckers badly, while *P. orthosepala* does not appear to do so, though possibly if grown under the same conditions as regards cultivation it might show that character.

The fact that all this closely related material came to notice about 1880 suggested that possibly *Prunus orthosepala* might have been of Kansas origin and led to a careful examination of Dr. Engelmann's notes and some of his correspondence, but without discovering anything concerning the origin of this species or, in fact, without finding mention of any form that could be interpreted as referring to it.

Prunus orthosepala, as it grows in the Arnold Arboretum and in Mr. Kerr's nursery, bears rather sparingly, but Mr. Kerr suggests that this may be due to the want of proper pollinizers. A specimen in Highland Park, Rochester, N. Y., where a number of other species are

also grown, produced a very good crop of fruit in 1911. The fruit of *P. orthosepala* is considered excellent in quality, and the Laire bears abundantly and is considered an excellent plum. It is possible that all of these forms represent natural hybrids of *P. americana* and the sand plum, both of which occur in northern Kansas; this would account for the variation and possibly also for their rare occurrence. Whatever their origin and whether they represent a natural species or hybrids, they are unquestionably promising, at least for the Plains region of Kansas and Oklahoma.

PRUNUS ALLEGHANIENSIS Porter.

(Northern sloe.)

Prunus alleghaniensis Porter, 1877, in Bot. Gaz., v. 2, no. 5, p. 85.

Leaves lanceolate to oval-lanceolate (Pl. V, fig. 2) or sometimes broadest above the middle and slightly oblanceolate, mostly 6 to 9 cm. long, 2 to 3 cm. broad, acute or acuminate, the margin finely and sharply serrate, very rarely doubly serrate, with or without glands near the base of the blade, green and glabrous or sparingly pubescent above and pale green below, usually pubescent, at least when young, sometimes becoming glabrous with age, midvein prominent; petiole 7 to 12 mm. long, pubescent, at least on the upper side, rarely glandular at the apex; stipules linear with bright reddish glands along the margin. Flowers appearing before the leaves from the last of April to the middle of May, 10 to 12 mm. broad, in nearly sessile umbels of 2 to 4; pedicels mostly 9 to 10 mm. long, slender, sparingly hairy or glabrous; calyx narrowly obconic, pubescent or sometimes glabrous, at least in cultivated specimens, the tube about 3 mm. long and obscurely ribbed, the lobes narrowly oblong-ovate, about 2 mm. long, erect, sparingly hairy or glabrous within; petals about 5 mm. long, round-obovate and abruptly narrowed to a short claw, the margin entire or sparingly erose toward the apex, white, turning pinkish with age. Fruit subglobose or somewhat oval or obovoid, about 10 mm. in its greatest diameter, very dark purple and covered with bluish bloom, flesh yellow, ripening in August; stone (Pl. XII, figs. 1 to 3) 11 to 12 mm. long, 8 mm. broad, slightly obovoid and rather obtuse at the apex, turgid, the ventral edge rather thick and grooved and the dorsal edge obscurely grooved, the surface obscurely roughened.

The species is a shrub 3 to 6 feet high, or more rarely a small tree 12 or more feet high, often forming thickets of considerable extent; branches rarely spinescent, bark of the larger branches comparatively smooth, very dark gray, that of the young twigs reddish brown and somewhat lustrous, pubescent or frequently glabrous, lenticels oval or round, slightly raised, yellowish brown; winter buds ovate, the scales slightly hairy or glabrous.

Prunus alleghaniensis (fig. 3) was described as occurring from Huntingdon County, Pa., on the limestone bluffs of the Little Juniata, northward through the barrens and westward over the Alleghenies as far as the extremity of Bear Mountain, Elk County. Specimens of the species were distributed to various American herbaria, and it was grown on the Lafayette College campus, Easton, Pa. It is grown in the Arnold Arboretum, Jamaica Plain, Mass., the tree there being about 18 feet high, and in the arboretum of the Central Experimental Farm near Ottawa, Canada, though it does not appear to be very hardy in the latter locality. It has been found in Connecticut, at Lisbon, sandy bottoms along the Quinebaug River; at Lyme, bank of the Connecticut River; at Bridgeport "about 100 plants 10 to 16 feet high," in a wet thicket bordering a small stream; at Monroe, in a hillside pasture; and at Southbury, by a roadside, in sandy soil.

The fruit is used locally, but it does not appear to have been utilized in any way in horticulture.

PRUNUS ALLEGHANIENSIS DAVISII W. F. Wight.

Leaves ovate or oval (Pl. V, fig. 3) 4.5 to 8 cm. long, 2.5 to 4 cm. broad, narrowed or rounded at the base, acute or sometimes slightly acuminate at the apex, the margin serrate with acute teeth, green and glabrous above, pale below and glabrous except along the rather prominent midvein, occasionally with a gland on either side near the base of the blade; petioles 6 to 10 mm. long, pubescent, rarely with a gland near the apex. Flowers 8 to 9 mm. broad, appearing in May before the leaves, in umbels of 2 to 4; pedicels 6 to 9 mm. long, glabrous; calyx obscurely and sparingly hairy, the tube obconic, 2.5 to 3 mm. long, the lobes oblong-ovate, about 2 mm. long, eglandular, bidentate at the apex or entire and acute, the inner surface rather densely pubescent with longish hairs; petals obovate, 5 to 6 mm. long and 3 to 4 mm. broad, narrowed to a claw, entire or erose toward the apex. Fruit subglobose or slightly oval, about 15 mm. in diameter, dark purple or almost black with a bluish bloom, ripening in September, the quality usually poor; stone ovate and pointed at each end (Pl. XII, figs. 4 to 6) or sometimes obtuse at the apex, 10 mm. long, 6.5 mm. broad and 5 mm. thick, rounded on the ventral edge with a shallow groove on either side, grooved along the dorsal edge, the surface obscurely roughened or reticulated.

Prunus alleghaniensis davisii is a shrub 3 to 9 feet high, the young twigs reddish chestnut, almost lustrous, turning gray or brownish the following year; lenticels round and lighter colored.

It is occasionally found in thickets along gravelly ridges from the southern part of Roscommon County northeastward for about 60 miles to the vicinity of Atlanta, in Montmorency County, Mich., and doubtless careful search will show a wider distribution.

Type specimens in the economic collection of the United States Department of Agriculture were collected, flowers, May, 1910, by O. F. Barnes, about 10 miles northeast of Roscommon, foliage and fruit September 23, 1910, by W. F. Wight, No. 4698, about 4 miles south of Houghton Lake, Mich. Attention was first called to this plum by C. A. Davis, of the United States Geological Survey, who had observed a blue-fruited plum of the *maritima* type growing along the gravelly ridges in the region south of Houghton Lake. Mr. Davis believed it would be found to be an undescribed species, and it is accordingly named for him. It differs from the species mainly in its leaves, which are broader in proportion to their length and less acuminate toward the apex. It may be distinguished from *Prunus maritima* by the reddish color of the young twigs, the more glabrous leaves, glabrous pedicels, and by the stone being pointed instead of rounded at the base.

The fruit is used locally in making jellies and conserves.

PRUNUS UMBELLATA Elliott.

(Sloe.)

Prunus umbellata Elliott, 1816, Sketch Bot. S. C. and Ga., v. 1, p. 541.

Leaves lanceolate, oblong-lanceolate or oval (Pl. V, fig. 4), 4 to 7 cm. long, 1.2 to 3 cm. broad, in age becoming rather firm in texture, narrowed or rarely rounded at the base, usually acute at the apex, the margin finely serrate with acute, incurved, rarely gland-tipped teeth, glabrous above, usually pubescent below along the midrib, and sometimes also along the lateral veins and the margin of the blade toward the base, marked with one or two glands near the base of the blade or toward the apex of the petiole, or eglandular; petioles mostly 5 to 7 mm. long, pubescent, at least along the upper surface. Flowers 10 to 18 mm. broad, appearing before the leaves the last of February or in March, in umbels of 2 to 4; pedicels 8 to 10 mm. long, slender and glabrous; calyx tube narrowly obconic, glabrous, about 3 mm. long, the ovate, obtuse lobes 1.5 to 2 mm. long, very obscurely hairy without, more strongly pubescent within, entire or minutely toothed at the apex, mainly erect at anthesis; petals oblong-obovate to nearly orbicular, 4 to 6 mm. long. Fruit globose, about 12 to 20 mm. in diameter, red, yellow, or more often dark purple when fully ripe, and covered with a glaucous bloom, ripening from the last of July to September; stone oval or nearly globose (Pl. XII, figs. 7 to 13), about 11.5 to 15 mm. long, 8.5 to 11 mm. broad, 6.5 to 8 mm. thick, obtuse or sometimes slightly pointed at the ends, variously grooved near the ventral and usually along the dorsal edge, the surface smooth or reticulate.

The tree is 15 to 20 feet high, forming a compact head; bark of the trunk dark brown, separating into small appressed scales; branches often somewhat spinescent, clothed with dark-brown bark, that of the young twigs glabrous, dark reddish brown, and marked with oval or round lenticels.

The species (fig. 3)¹ was originally described from "very dry, sandy soils," in South Carolina and Georgia, and extends southward in Florida to Tampa, and westward at least to the Apalachicola River. In the coast region of eastern Florida it appears to have a larger, more turgid, often more nearly globose stone than in the western part of its range from which material has been seen, but otherwise it does not differ. In some localities the fruit is commonly

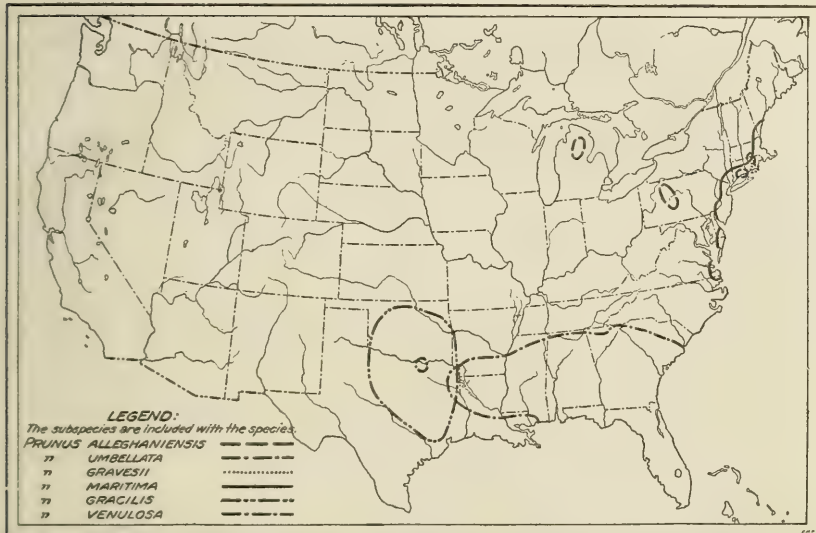


FIG. 3.—Outline map of the United States, showing the distribution of native American species of *Prunus*: *Alleghaniensis*, *umbellata*, *gravesii*, *maritima*, *gracilis*, and *venulosa*.

yellowish. Dr. Hugh M. Niesler, writing from Taylor County, Ga., in 1860, says:

The fruit is much smaller [than *P. angustifolia*] and exceedingly sour, its color yellowish red—the yellow predominating, but still a color which I have never seen approached very closely by any Chicasa plum. I have never seen the tree elsewhere than along the streams and around the fields near Columbus.

The fruit is occasionally gathered and used for preserves.

PRUNUS UMBELLATA INJUCUNDA (Small) Sargent.

Prunus injucunda Small, 1898, in Bul. Torrey Bot. Club, v. 25, no. 3, p. 149.

Prunus mitis Beadle, 1902, in Baltimore Bot. Studies, v. 1, no. 2, p. 162.

Prunus umbellata injucunda Sargent, 1902, Silva N. Amer., v. 13, p. 21.

¹ The Elliott herbarium is preserved in the Charleston (S. C.) Museum.

Leaves oval or oblong-oval, mostly 5 to 8 cm. long, 2 to 3.5 cm. broad, narrowed toward the base, acute or acuminate at the apex, obscurely pubescent above, pubescent below, sometimes strongly so, very rarely glabrous except along the midvein; petioles 5 to 9 mm. long, pubescent. Flowers appearing in March or April, 12 to 15 mm. broad; pedicels and calyx usually pubescent, sometimes obscurely so. Fruit similar to the species; stone oval and usually pointed at both ends, about 13 mm. long.

Prunus umbellata injucunda ranges from the extreme southwestern part of North Carolina through the hill country of Georgia to Mississippi, and probably merges imperceptibly into the subspecies *P. umbellata tarda*.

Prunus umbellata injucunda was described as a species from "sandy soil on the granite districts from Stone Mountain, Ga.," and the type collected by John K. Small, July 7, 1893, is in the herbarium of the New York Botanical Garden. This represents a form with extremely pubescent foliage and branchlets. *Prunus mitis* was described from specimens collected at Auburn, Lee County, Ala., March 27 and May 20, 1900, by F. S. and Esther S. Earle, No. 27, and type material is preserved in the Biltmore Herbarium. This form has less pubescent foliage and glabrous twigs, but numerous specimens show various intermediate stages, some from the same region on sandy soil having glabrous twigs while those on clay soil were strongly pubescent, the trees differing in no other character.

PRUNUS UMBELLATA TARDA (Sargent) W. F. Wight.

Prunus tarda Sargent, 1902, in Bot. Gaz., v. 33, No. 2, p. 108.

Leaves oblong-oval or rarely obovate, narrowed at the base, acute or shortly acuminate at the apex, 4 to 8 cm. long, 1.5 to 3.5 cm. broad, dull yellowish green, finely and obscurely pubescent or glabrate above, pale and somewhat pubescent below, at least along the midrib and prominent lateral veins, the margins serrate with acute somewhat incurved teeth; petioles tomentose. Flowers appearing in April, about 12 mm. broad; pedicels glabrous; calyx tube sparingly pubescent without, more strongly hairy within; petals oblong-obovate, 5 to 6 mm. long. Fruit subglobose or slightly oval, 10 to 15 mm. in diameter, yellow, purple, red, or dark blue in color, with a bloom, ripening in October and November; stone as in the preceding.

The tree is 18 to 25 feet high, with light reddish brown bark exfoliating in small platelike scales, that of the branchlets somewhat lustrous. *Prunus umbellata tarda* is very similar to the species, but may be distinguished by its lighter bark, later ripening fruit, and more oblong stone. The type specimens, collected on April 19, 1901,

by William M. Canby, B. F. Bush, and C. S. Sargent, are in the herbarium of the Arnold Arboretum.

This form is distributed through western Mississippi, Louisiana, and southern Arkansas to the vicinity of Marshall, Tex., the type locality.

PRUNUS MARITIMA Marsh.¹

(Beach plum.)

Prunus maritima Marsh., 1785, Arb. Amer., p. 112.

Prunus pygmaea Willd., 1796, Berl. Baumz., p. 248.

Prunus sphaerocarpa Michx., 1803, Fl. Bor. Amer., t. 1, p. 248.

Prunus acuminata Michx., 1803, Fl. Bor. Amer., t. 1, p. 284.

Prunus sphaerica Willd., 1811, Berl. Baumz., Aug. 2, p. 315.

Prunus pubescens Pursh., 1814, Fl. Amer., Sept., v. 1, p. 331.

Prunus littoralis Bigel., 1824, Fl. Bost., ed. 2, p. 193.

Prunus pubigera Steud., 1841, Nom. Bot., ed. 2, part 2, p. 404.

Leaves ovate, elliptic, or rarely somewhat obovate (Pl. V, fig. 1), narrowed toward the base and acute at the apex, 4 to 6.5 cm. long, 2 to 4 cm. broad, the margin evenly and sharply serrate, dull green and glabrous or nearly so above, pale and soft-pubescent, sometimes appearing grayish below, often with a gland on either side near the base of the blade; petioles rather stout, 4 to 6 mm. long, pubescent. Flowers 12 to 14 mm. broad, in umbels of 2 to 3, appearing before the leaves, in May or early in June; pedicels and calyx rather strongly pubescent, pedicels 5 or usually 7 mm. long; calyx tube campanulate, about 2 mm. long, the oblong obtuse lobes as long as the tube, entire or dentate at the apex, eglandular, pubescent within with rather short hairs; petals oblong or oblong-ovate, about 7 mm. long, 4 mm. broad, abruptly narrowed to a claw. Fruit globose or slightly flattened at the ends, about 15 mm. in diameter, dull purple, with a heavy bloom, sometimes crimson or even yellow, ripening in August on the New Jersey coast and in September on the coast of Massachusetts, flesh sweet; stone ovate and turgid (Pl. XII, figs. 14 to 17), about 10 mm. long, 9 mm. broad, and 6 mm. thick, truncate or rounded at the base, usually pointed at the apex, a little narrowed on the ventral edge with a groove on either side, obscurely grooved along the dorsal edge, the surface usually slightly reticulate.

Prunus maritima is a straggling shrub mostly 3 to 6 or rarely 8 feet high, with the lower branches decumbent or often prostrate; bark very dark gray or brownish, usually marked with numerous round, sometimes raised, yellowish lenticels; young twigs usually pubescent.

The species is distributed (fig. 3) in sandy soil near the seacoast from

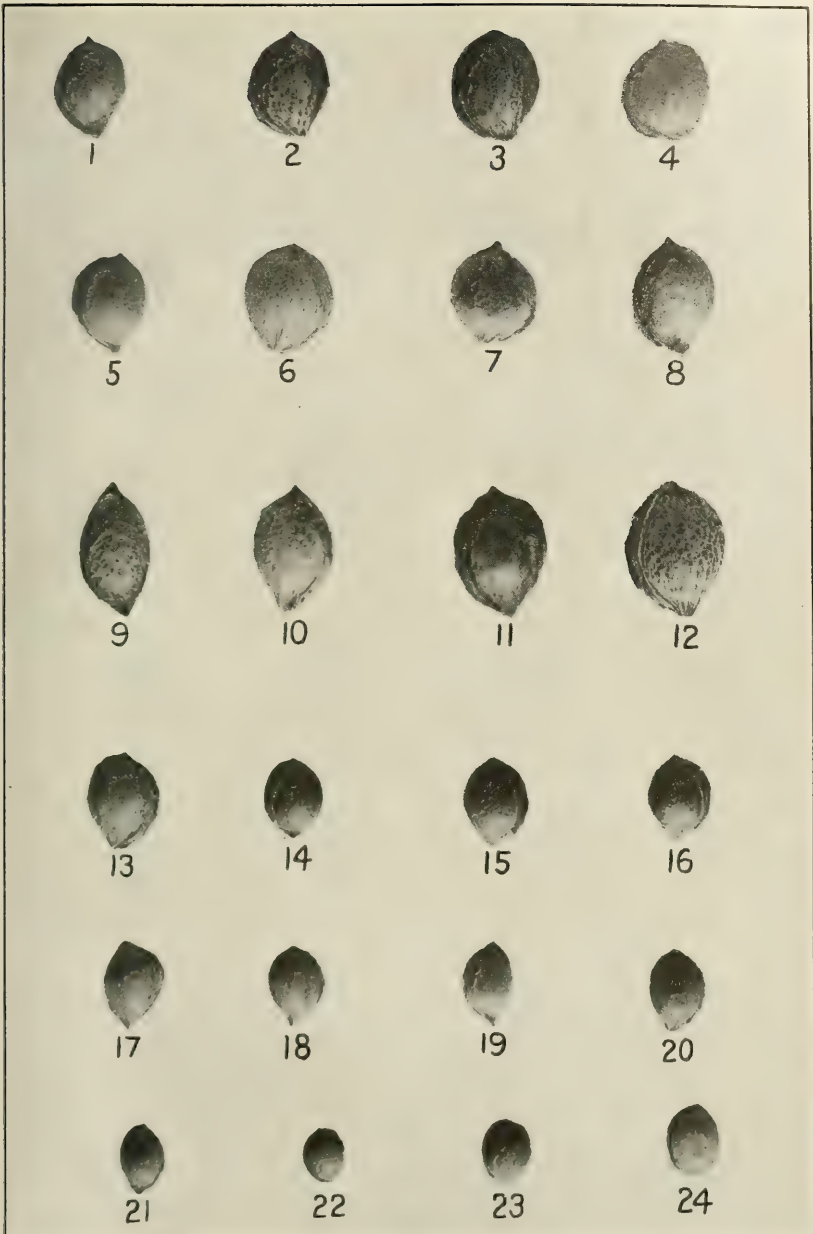
¹ The authority usually given for this species is Wangenheim (1781, p. 103). This author published (74) in 1781 *Beschreibung einiger Nordamerikanischer Holz- und Buscharten, mit Anwendung auf deutsche Forsten*. Two copies of this work have been carefully searched, but without finding any trace of the name *Prunus maritima*. In another work (75), published in 1787, Wangenheim describes this species on page 103. It seems probable that an error has been made in the date of Wangenheim's publication and that Marshall is really the author of the species.

the vicinity of Scarboro, Me., to Fortress Monroe, Va. It occasionally occurs a few miles inland in Connecticut, and in New Jersey it ranges inland to within about 12 miles of Camden and to Bordentown; it has also been collected at Sellersville, Pa.

Prunus maritima is recorded by Chapman (13, p. 131) from Alabama, and the basis of this record is an imperfect specimen collected by Buckley. Sargent thinks (66, p. 28) it possible that this specimen represents a form of *P. alleghaniensis*. It is much more probable, however, that it is *P. umbellata injucunda*. The species has also been reported from the shores of Lake Michigan (32, p. 33; 5, p. 214) in the vicinity of Chicago and near the head of the lake. Most of the specimens cited by Higley and Raddin are in the herbarium of the Northwestern University, and all of these were found to be *P. pumila*. A considerable part of the region about the head of the lake was explored the past summer, but without finding any trace of *P. maritima*. A letter from E. J. Hill, who went to Chicago in 1874 and has probably studied the flora of the region as carefully as any one, states that he has never found the species there, although familiar with its reported occurrence.

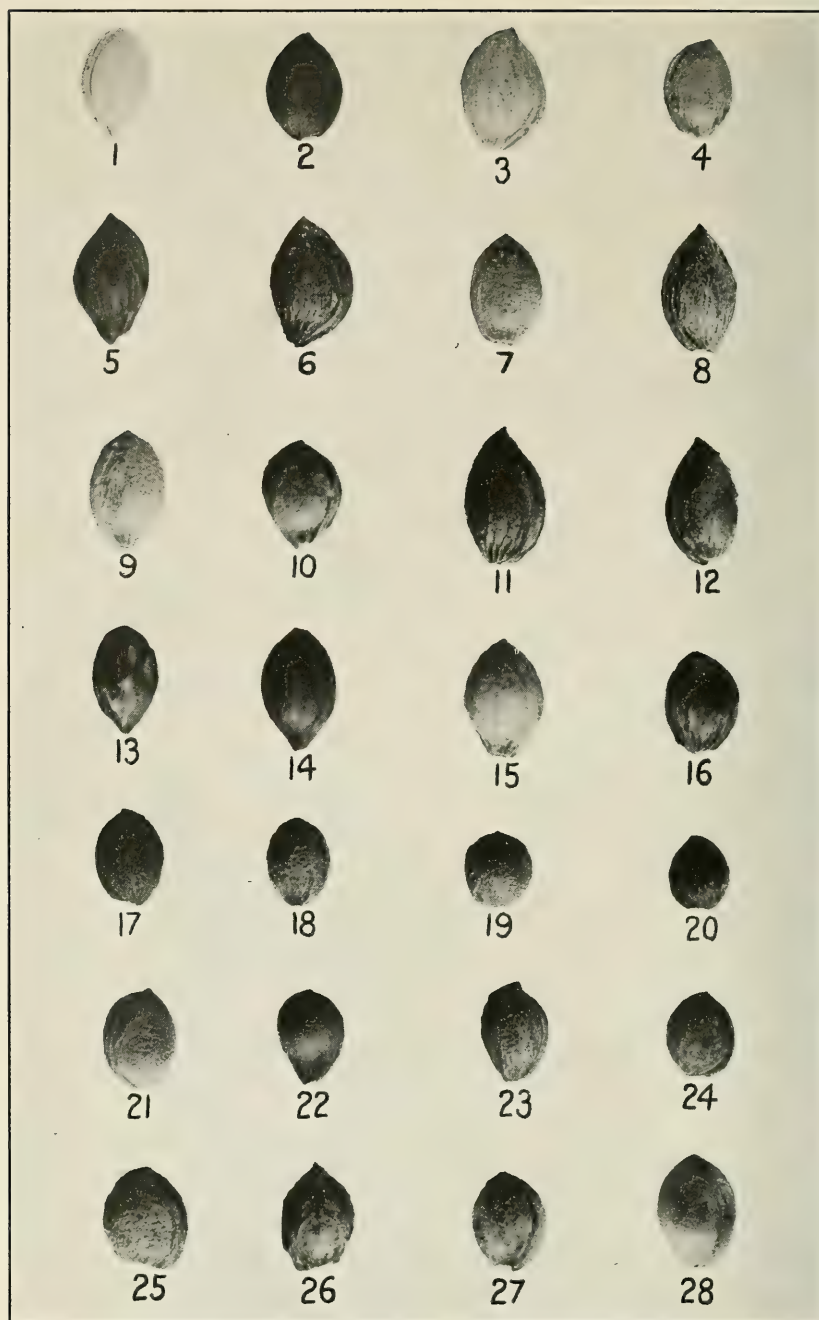
Prunus sphaerocarpa was described from the New England seacoast; *P. declinata* was very briefly described and no locality given, but the description apparently refers to the beach plum; *P. acuminata*, "Hab. in Virginia," is apparently also this species, although it can scarcely be positively identified from the description alone; *P. pygmaea* was described from garden material grown from North American seed and distributed as *Prunus maritima* by the "Herrn von Wangenheim"; *P. pubescens* was apparently based in part on *P. sphaerocarpa* Michx. "on the seacoast of New England" (not on *P. sphaerocarpa* Swartz), and on material collected "in the western parts of Pennsylvania, on the borders of lakes," the latter locality unquestionably representing a different species. *P. littoralis* and *P. sphaerica* are also apparently based on *P. sphaerocarpa* Michx.; *P. pubigera* is based on "*P. pubescens* Poir. (non. Pursh.)." Poiret does not describe a new species, but quotes the description of Pursh.

Prunus maritima is an attractive ornamental, on account of the profusion of its bloom, and it is occasionally planted in the East. It has given rise to a few named varieties, Bassett (5, p. 214), Alpha, and Beta, and the fruit is frequently gathered from wild trees. When grafted and grown under favorable conditions, it sometimes becomes a small tree. This species attracted the attention of horticulturists comparatively early and was apparently often considered quite as valuable as *Prunus americana*. No doubt fruit was often found as large and as palatable as that of *P. americana* in the eastern part of its range, but when horticultural development in the West brought to the attention of pomologists the better forms of the latter and of other species, *P. maritima* gradually ceased to be mentioned.



STONES OF THE NATIVE AMERICAN SPECIES OF PRUNUS.—III.

FIGS. 1 to 12.—*Prunus hortulana*: 1, From a wild tree near Terre Haute, Ind.; 2, from Courtney, near Kansas City, Mo.; 3, from Allenton, Mo.; 4, 5, and 6, from Joplin, Mo.; 7, Read variety; 8, Golden Beauty; 9, World Beater; 10, Wayland; 11, Maquoketa; 12, Miner. FIGS. 13 to 22.—*Prunus reverchonii*: 13, 14, 15, 16, and 17, From a wild shrub near Denison, Tex.; 18, from McKinney, Tex.; 19, from Henrietta, Tex.; 20, from Waco, Tex.; 21 and 22, from near Henrietta, Tex. FIGS. 23 and 24.—*Prunus rivularis*: From a wild shrub, San Antonio, Tex. (Natural size.)



STONES OF THE NATIVE AMERICAN SPECIES OF PRUNUS.—IV.

FIGS. 1 to 16.—*Prunus munsoniana*: 1, From a wild tree, Allenton, Mo.; 2, from Fulton, Ark.; 3, Arkansas variety; 4, from near Denison, Tex.; 5, from near Henrietta, Tex.; 6, Downing variety; 7, Miles; 8, Milton; 9, Newman; 10, Texas Belle; 11 and 12, Wild Goose; 13, Wooten; 14, Poole Pride; 15, Robinson; 16, Smiley. FIGS. 17 to 28.—*Prunus angustifolia*: 17, From a wild tree near Washington, D. C.; 18, from Denton, Md.; 19, from Jacksonville, Fla.; 20, from Lee County, Ala.; 21, from near Denison, Tex.; 22, from Ellis, Kans.; 23, from Motley County, Tex.; 24, Strawberry variety; 25, Caddo Chief; 26, Fawn; 27, Piram; 28, Yellow Transparent. (Natural size.)

PRUNUS MARITIMA HYBRIDS.

Hybrids have been produced by Luthur Burbank and J. W. Kerr. Among those secured by Mr. Kerr are several of remarkably clean foliage and vigorous character, probably with *Prunus triflora* as one of their parents. At least one of these has fruit $1\frac{1}{4}$ inches in diameter, although not of very good quality. Nevertheless, this species shows evidence of much promise, and with a careful search among wild trees for fruit of good quality as a basis something of value may ultimately be secured. (Pl. XIII, fig. 10.)

PRUNUS GRAVESII Small.

Prunus gravesii Small, 1897, in Bul. Torrey Bot. Club, v. 24, No. 1, p. 45.

Leaves orbicular to oblong-orbicular, 18 to 30 mm. long, 20 to 25 mm. broad, the margin sharply serrate, green and finely pubescent or glabrate above, pale green below and pubescent, at least along the veins; petioles about 3 mm. long, pubescent; stipules linear, glandular, and pubescent. Flowers appearing before or with the leaves from the middle to the last of May, in umbels of 2 to 3 or sometimes solitary, about 10 to 15 mm. broad; pedicels and calyx pubescent, pedicels about 6 mm. long; calyx tube 2.5 to 3 mm. long, the ovate, obtuse lobes 2 to 2.5 mm. long, pubescent on both surfaces, eglandular; petals about 5 mm. long, orbicular, and contracted near the base to a distinct claw. Fruit globose, 10 to 15 mm. in diameter, deep purple with light-blue bloom, slightly astringent, ripening early in September; stone subglobose or broadly oval (Pl. XII, figs. 18 and 19), about 8 by 6.5 by 5.5 mm., obscurely ridged on the dorsal and thickened on the ventral edge, with a line along the center and an indistinct ridge a short distance back on either side.

The species is a low, unarmed shrub scarcely more than 3 feet high, with a dark, rather rough bark and usually puberulent twigs.

This rare species is related to *Prunus maritima* and is known only from the original locality at Groton, Conn., where it grows on a gravelly ridge near Long Island Sound (fig. 3). The species was discovered and the type specimens (in the herbarium of the New York Botanical Garden) collected by Dr. Charles B. Graves, for whom it is named.

PRUNUS GRACILIS Engel. and Gray.

Prunus gracilis Engelm. and Gray, 1845, in Boston Jour. Nat. Hist., v. 5, No. 2, p. 243.

Prunus chicasa normalis Torr. and Gray, 1840, Fl. N. Amer. v. 1, p. 407.

Prunus normalis Small, 1903, Fl. Southeast. United States, p. 572.

Leaves oval (Pl. VII, fig. 1), rarely ovate, or still more rarely obovate-lanceolate, 2.5 to 5 cm. long, 1.5 to 2.5 cm. broad, pointed at each end or rarely obtuse at the apex, finely and obscurely pubescent

above, pale and strongly pubescent and reticulate below, the margin finely serrate with acute or sometimes obtuse teeth, these gland tipped when young, the blades with or without a gland on either side near the base; petioles 5 to 8 mm. long, pubescent and eglandular, or with one or two glands near the apex. Flowers 9 or 10 mm. broad, appearing before the leaves from the middle of March to about the middle of April, in umbels of 2 to 4; pedicels and calyx finely pubescent, the pedicels 7 to 10 mm. long; calyx tube campanulate, 2.5 mm. long, the lobes ovate and acute, entire or minutely dentate toward the apex, 1.5 to 2 mm. long, eglandular, pubescent on both surfaces; petals obovate to obovate-orbicular, 4 to 5 mm. long and about 3 mm. broad. Fruit globose or slightly oval, 14 to 18 mm. in diameter, usually red, with a light bloom, ripening from the middle of June in the South to early in August and said to be quite palatable; stone oval (Pl. XII, figs. 20 and 21), about 13 mm. long, 9 mm. broad, and 6 mm. thick, somewhat obtuse at the ends, a thick wing on the ventral edge, with a groove on either side and a shallow groove along the dorsal edge, the surface nearly smooth.

Prunus gracilis is a small, straggling shrub 1 to 4 feet high, growing in scattered clumps or forming loose thickets; bark of the stem grayish, that of the young twigs pubescent, dull reddish brown turning to gray during the first winter.

Its area of distribution (fig. 3) is from northern Oklahoma and the extreme western part of Arkansas southward to the Colorado River, in Texas. The Tennessee locality frequently cited appears to be based on the young foliage of *Prunus mexicana*.

The following note is taken from a specimen labeled "Arkansas River, Ind. Terr., 1882."

It seldom attains a greater height than 4 feet and when in full fruitage lays down upon the grass beneath it, vinelike. The fruit is larger when found on larger shrubs. It abounds only on sandy soil and delights in a sand bluff. Millions of this fruit grow on the Arkansas River and its tributaries in Kansas [?] and the Indian Territory. It is finely flavored and of every shade of color when ripe; different specimens ripen at different dates, so "plum season" is a long one.

Mr. T. V. Munson says it is especially subject to the attacks of the "black-knot" fungus (*Plowrightia morbosa* (Schw.) Sacc.), and for that reason he endeavored to destroy a small thicket growing in his nursery at Denison, Tex.

Prunus chicasa normalis was described from "Texas and Arkansas, Dr. Leavenworth; Texas, Drummond." These specimens are in the herbarium of the New York Botanical Garden. That of Drummond from Texas is *P. gracilis*. Dr. Leavenworth's Arkansas specimen is labeled "*Prunus chicasa* β . Prairies of Arkansas, April," and appears to be *P. angustifolia*. The Texas sheet of this collector has two specimens, one in flower, which is *P. gracilis*, and the other with foliage and fruit, which does not appear to be this species. *P. gracilis*

appears to have been based on the collection of Lindheimer, "Open post-oak woods west of the Brazos, where it is called 'post-oak plum,'" specimens of which are in both the Missouri Botanical Garden herbarium and the Gray herbarium. They are all *P. gracilis*.

PRUNUS VENULOSA Sargent.

Prunus venulosa Sarg., 1911, *Trees and Shrubs*, v. 2, pt. 3, p. 157.

Leaves ovate to oblong-ovate (Pl. VII, fig. 2), mostly 5 to 7 cm. long, 2.5 to 3.5 cm. broad, gradually rounded at the base and acute or abruptly acuminate at the apex, dull green and glabrous or sometimes sparingly hairy above with short appressed hairs, very reticulate veiny below, and usually rather strongly pubescent with short hairs, becoming less so with age, the margins serrate and apparently glandular when young, but the glands falling away and usually leaving the serrations more or less obtuse, leaf blades only slightly or not at all folded when pressed; petioles 10 to 12 mm. long, with or without one or two glands near the apex, pubescent along the upper surface. Flowers 6 to 7 mm. broad, appearing before the leaves during the latter part of March, in umbels of 2 to 4; pedicels 3.5 to 5 mm. long, glabrous or nearly so; calyx campanulate, glabrous or sparingly pubescent, the tube about 1.5 mm. long, the lobes scarcely more than 1 mm. long, ovate, the margin glandular and slightly ciliate, sparingly hairy within toward the base; petals 2.5 to 3 mm. long, orbicular and abruptly contracted to a very short claw, arose toward the apex or entire. Fruit globose, 14 to 20 mm. in diameter, dark red, ripening in July, and poor in quality; stone oval (Pl. XII, figs. 22 to 24), 10 to 11 mm. long, 8 to 9 mm. broad, and about 6.5 mm. thick, somewhat pointed at the base and rounded at the apex, irregularly grooved and ridged near the ventral edge and with a shallow groove along the dorsal edge, the surface smooth.

Prunus venulosa is a small shrub 3 to 6 feet high, forming dense thickets. Bark of the stem dark gray, the young twigs finely pubescent or glabrate, dull reddish chestnut turning dark gray with age, marked with lighter colored oval lenticels.

The species is known only from a few localities in the vicinity of Denison, in northern Texas (fig. 3).

Prunus venulosa is more nearly related to *P. gracilis* than any other species, but it is a larger shrub and forms more dense thickets, the leaves are larger and more coarsely serrate, and the pedicels of the flowers are glabrous or nearly so, while they are strongly pubescent in *P. gracilis*. The type specimens are preserved in the herbarium of the Arnold Arboretum. Horticulturally the species shows no promise whatever. Its rare occurrence as well as its general character suggests that it may possibly be of hybrid origin, and if so, the species concerned are *P. gracilis* and *P. reverchonii*.

PRUNUS PENNSYLVANICA L. f.

(Bird cherry. Pin cherry.)

Prunus pennsylvanica L. f., 1781, Suppl. Pl., p. 252.*Prunus persicifolia* Desf., 1809, Hist. Arb., pt. 2, p. 205.*Prunus montana* Marsh., 1785, Arb. Amer., p. 113.*Prunus lanceolata* Willd., 1796, Berl. Baumz., p. 240.

Mature leaves lanceolate (Pl. VI, fig. 1), oblong-lanceolate or oval-lanceolate, narrowed or rounded at the base, acuminate toward the apex, the young leaves at first oval or ovate, sometimes slightly falcate, 6 to 12 cm. long, 1.5 to 4 cm. broad, the margin finely serrate with glandular incurved teeth, entirely glabrous or slightly pubescent below along the prominent midvein and the lateral veins near their junction with the midvein, or, when young, sometimes sparingly and inconspicuously pubescent on the lower surface; stipules linear and glandular serrate. Flowers 9 to 12 mm. broad, appearing with the half-grown leaves from early in May to the last of June in the northern part of its range, 3 to 7 together in umbellike or sometimes corymblike clusters, the latter sessile or sometimes short stalked; pedicels 12 to 18 mm. long, slender and glabrous; calyx obconic, glabrous, the tube 2.5 to 3 mm. long, the oblong or ovate-oblong obtuse lobes about 2 mm. long, eglandular, reflexed at anthesis; petals about 5 mm. long, oblong-orbicular and abruptly contracted to a short claw, sometimes slightly pubescent on the outer surface near the base. Fruit globular, with thin flesh, 6 to 7 mm. in diameter, red, ripening from the middle of July to the first of September; stone oblong-oval to roundish oval (Pl. XII, figs. 35 to 37), 5 to 6 mm. long, with a thickened obscurely grooved ridge on the ventral side.

Prunus pennsylvanica sometimes attains a height of 30 or 35 feet, often sprouting from the roots and forming thickets. The bark of the older trunks is somewhat scaly, while that of the smaller trunks and branches is rather smooth and reddish brown, marked with prominent horizontal bands of lenticels. It separates in horizontal papery strips, resembling the birch in this respect. The bark of the young twigs is reddish and somewhat lustrous.

Prunus pennsylvanica ranges (fig. 4) from Newfoundland and New England westward through the valley of the St. Lawrence, Pennsylvania, northern Ohio, and northern Indiana to the Black Hills and the eastern slopes of the Rocky Mountains, where it passes into the subspecies. It apparently does not occur north of Lake Huron, but extends northwestward from the western end of Lake Superior to the Winnipeg Valley. It is reported to extend to the shores of Hudson Bay (66, p. 36), but no specimens have been seen from that region. It is common in the Alleghenies from Pennsylvania south-

ward to southwestern North Carolina and is said to reach its greatest size in this region.

The fruit of this species is not edible, but the tree is sometimes used as a stock on which to bud the sour cherry (*Prunus cerasus*) and in northern regions is the only stock on which that fruit has as yet been successfully grown. A. S. Fuller (25, p. 184) notes as early as 1867 that the wood of this species and that of the cherry unite very readily.

PRUNUS PENNSYLVANICA CORYMBULOSA (Rydb.) W. F. Wight.

Prunus corymbulosa Rydb., 1900, Cat. Fl. Mont., p. 226.

Cerasus trichopetala Greene, 1905, in Proc. Biol. Soc. Wash., v. 18, p. 60.

Prunus trichopetala Blankinship, 1905, in Mont. Agr. Coll. Sci. Studies, Bot., v. 1, No. 2, p. 70.

Prunus pennsylvanica saximontana Rehder, 1908, in Mitt. Deut. Dendrol. Gesell., No. 17, p. 160.

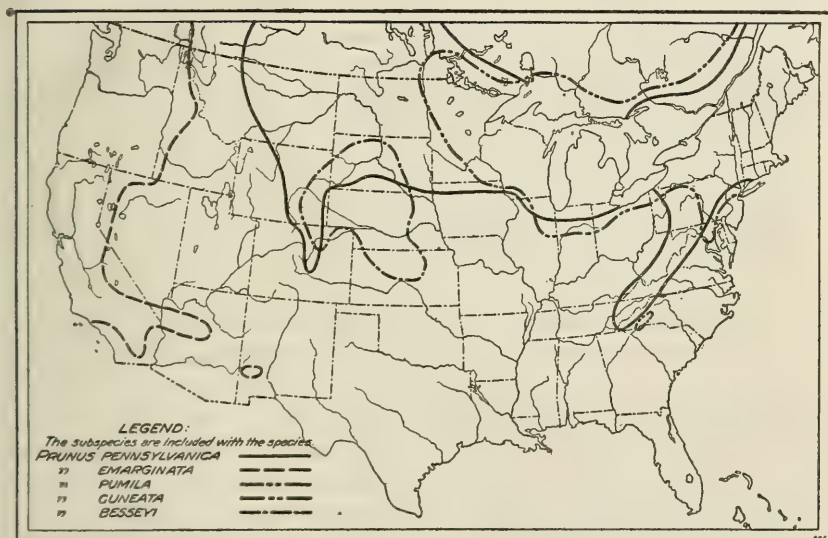


FIG. 4.—Outline map of the United States, showing the distribution of native American species of *Prunus: pennsylvanica, emarginata, pumila, cuneata, and besseyi*.

Leaves ovate to ovate-lanceolate or sometimes oblong-oval (Pl. VI, fig. 2), narrowed toward the base, acute at the apex. Flowers 12 to 18 mm. broad, in sessile or sometimes pedunculate clusters of three to six. Stone slightly ovoid, about 6 mm. long.

The subspecies forms a small shrub, 3 to 6 feet high, differing from the species in its shrubby character and in the mature leaves being broader in proportion to their length, and in the stone being slightly ovoid instead of round-oval.

Prunus pennsylvanica saximontana was described from Colorado, Wyoming, and the Black Hills region of South Dakota and was distinguished from the type of *P. pennsylvanica corymbulosa* by its sessile

flower clusters, but this appears to be a variable character both in the species and subspecies. The earliest name is therefore used to designate the low western form which occurs from Fort McMurray, in about latitude 57°, Alberta, southward along the eastern slope of the Rocky Mountains to central Colorado.

The proposed species *Cerasus trichopetala* was based on a flowering specimen collected by R. S. Williams, at Columbia Falls, Mont., May 24, 1894. The specimen differs in no way from other material of the subspecies. *Prunus corymbulosa* was described from the Bridger Mountains and the Little Rocky Mountains, Mont.

PRUNUS EMARGINATA (Dougl.) Walp.

Cerasus emarginata Dougl., 1834, in Hook. Fl. Bor. Amer., v. 1, p. 169.

Prunus emarginata Walp., 1843, Repert. Bot., t. 2, p. 9.

Cerasus glandulosa Kellogg, 1854, in Bul. Cal. Acad. Sci., v. 1, p. 59.

Cerasus californica Greene, 1891, Fl. Franc., [pt.] 1, p. 50.

Cerasus crenulata Greene, 1905, in Proc. Biol. Soc. Wash., v. 18, p. 56.

Cerasus arida Greene, 1905, in Proc. Biol. Soc. Wash., v. 18, p. 57.

Cerasus prunifolia Greene, 1905, in Proc. Biol. Soc. Wash., v. 18, p. 57.

Cerasus rhamnoides Greene, 1905, in Proc. Biol. Soc. Wash., v. 18, p. 58.

Cerasus kelloggiana Greene, 1905, in Proc. Biol. Soc. Wash., v. 18, p. 58.

Cerasus padifolia Greene, 1905, in Proc. Biol. Soc. Wash., v. 18, p. 59.

Cerasus obliqua Greene, 1905, in Proc. Biol. Soc. Wash., v. 18, p. 59.

Cerasus parvifolia Greene, 1905, in Proc. Biol. Soc. Wash., v. 18, p. 59.

Cerasus obtusata Greene, 1905, in Proc. Biol. Soc. Wash., v. 18, p. 60.

Prunus prunifolia Shafer, 1908, in Britt. and Shaf., N. Amer. Trees, p. 500.

Leaves oblong-oval, obovate, or sometimes lanceolate (Pl. VI, fig. 3), 3 to 5.5 cm. long, 1 to 2 cm. broad, narrowed or even cuneate toward the base and obtuse or sometimes acute at the apex, the margins serrate and the teeth tipped with minute, pointed, sometimes incurved glands, the base furnished with two or more larger dark-colored glands, or sometimes eglandular, more or less pubescent as they unfold, the upper surface at maturity green and glabrous, the lower pale and glabrous or marked with a few scattered hairs; petioles 5 to 9 mm. long, glabrous or pubescent with short hairs; stipules lanceolate and glandular serrate. Flowers 10 to 15 mm. broad, appearing with the leaves from early in April to the middle of June, according to the locality and altitude, in corymbose clusters of 5 to 10; the pedicels subtended by small foliaceous dentate or lacinate bracts 6 to 14 mm. long, glabrous or nearly so; calyx glabrous, campanulate, the tube about 3.5 mm. long, the oblong or ovate-oblong obtuse lobes slightly shorter; petals obovate, entire or erose, 4 to 5 mm. long, glabrous or sparingly hairy on the outer surface toward the base. Fruit globose, 8 to 10 mm. in diameter, ripening from July to the end of September, bright red in color when first fully grown, changing to nearly black when ripe, flesh thin, bitter, and astringent; stone oval or slightly ovoid (Pl. XII, figs. 38 to 40),

somewhat pointed at each end, ridged on the ventral and rounded on the dorsal edge, about 7 mm. long, 5 mm. broad.

Prunus emarginata is a shrub 3 to 10 feet tall or becoming a small tree in favorable situations, bark of the trunk dark brown, smooth, and rather conspicuously marked with bands of lenticels, grayish brown on the branches and smaller stems, the young twigs usually glabrous, reddish, turning gray at the end of the season. It often forms dense shrubby thickets.

The species was originally described from specimens collected near Kettle Falls in the Columbia River Valley, northeast Washington, and ranges (fig. 4) from the upper Joeko River, in Montana, through the mountains of Idaho and Washington and from southern British Columbia southward in both the coast and interior mountains of California and western Nevada to the San Bernardino Mountains, reappearing in the San Jacinto and at South Peak in the Cuyamaca Mountains, in California. It occurs in the San Francisco Mountains, in Arizona, and has been collected as far east as Flagstaff; and specimens from the Mogollon and Black Mountains, in southwestern New Mexico, are also referable to this species. It occurs near streams and on moist benches, sometimes in dryish gravelly soils but more often in moist gravelly or more fertile soils. It reaches an elevation of 5,000 feet in the North, in the Sierra Nevada it has been found at 8,000 feet, in the San Rafael Mountains at 5,000 feet, in the San Jacinto Mountains at 9,000 feet, and in the San Francisco Mountains at 6,000 feet.

Prunus emarginata was originally described as a "low shrub, 4 to 8 feet high, with very red wood marked with white spots, and astringent fruit. The leaves are about 2 inches long, quite glabrous, as is the whole plant." The species is quite variable, as is to be expected when the range, covering such varied conditions as are found in the Pacific slope, is taken into consideration. The proposed species here reduced to synonymy undoubtedly show slight differences from the original, but a study of a large amount of material shows these forms to be connected with each other and with the type by innumerable gradations. *Cerasus crenulata* was described from the Mogollon and Black Mountains, N. Mex.; *C. arida* from "Borders of desert at eastern base of the San Bernardino Mountain," Cal.; *C. prunifolia*, "8,000 feet in the mountains of Fresno County, Cal."; *C. rhamnoides*, "Mud Springs, Amador County, Cal."; *C. kelloggiana* from mountains east of Chico and from near Quincy, Cal.; *C. padifolia*, foothills at Carson City, Nev.; *C. obliqua*, Oroville, Cal.; *C. parvifolia* from the vicinity of Mount Shasta, Cal.; and *C. obtusata* from Silvies, in southeastern Oregon. *C. glandulosa* was described from Placerville, Cal., and from the description and locality can not be other than this species. While variable, a study in the field fails to reveal other than minor varia-

tions due to differences in the conditions under which it is found in its wide range.

So far as known, the species has not been utilized in horticulture.

PRUNUS EMARGINATA VILLOSA Sudworth.

Cerasus mollis Dougl., 1834, in Hook. Fl. Bor. Amer., v. 1, p. 169.

Prunus mollis Walp., 1843, Report Bot., t. 2, p. 9. (Not *P. mollis* Torr., 1824.)

Cerasus erecta Presl., 1849, Epim. Bot., p. 194.

Prunus erecta Walp., Ann. 3: 854, 1852-53.

Cerasus pattoniana Carr., 1872, in Rev. Hort., Ann. 44, p. 135, fig. 17.

Prunus emarginata mollis Brewer, 1876, in Brewer and Wats. Bot. Calif., v. 1, p. 167.

Prunus emarginata villosa Sudw., 1897, U. S. Dept. Agr., Div. Forestry Bul. 14, p. 240.

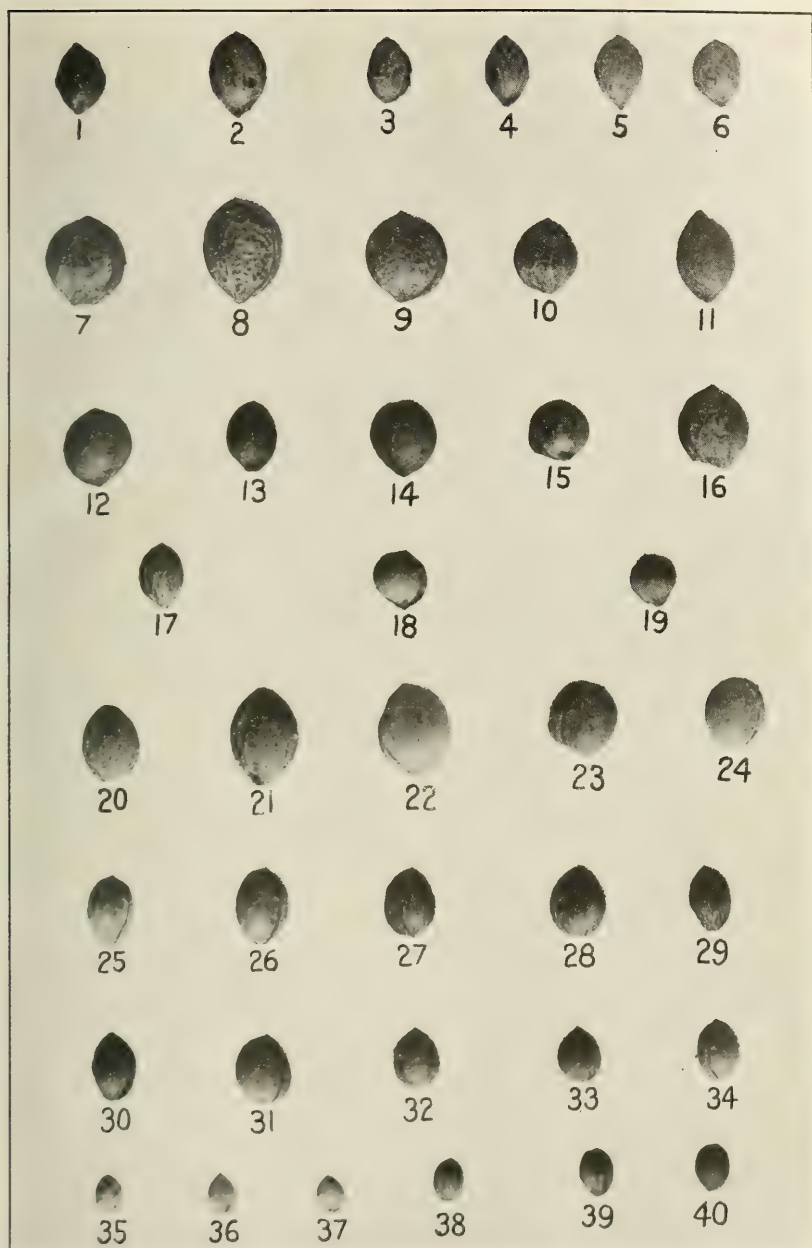
Leaves obovate to oval, 2 to 7 cm. long, or on vegetative shoots sometimes even 10 cm. long, 2 to 3 cm. broad, narrowed or cuneate at the base, obtuse or sometimes emarginate at the apex, more or less pubescent, at least on the lower surface. Flowers as in the species, except for the rather strongly pubescent pedicels and calyx tube, and the petals also more conspicuously pubescent. Fruit similar to the species.

The tree is 30 to 40 feet high with well-defined, straight trunk in the most favorable situations, the young twigs rather strongly pubescent.

This form is known to occur from the southern coast of Vancouver Island and southern British Columbia west of the mountains southward to southern Oregon. In the southern part of its range it occurs at an altitude of 4,000 feet, while in the north it is found only at low altitudes.

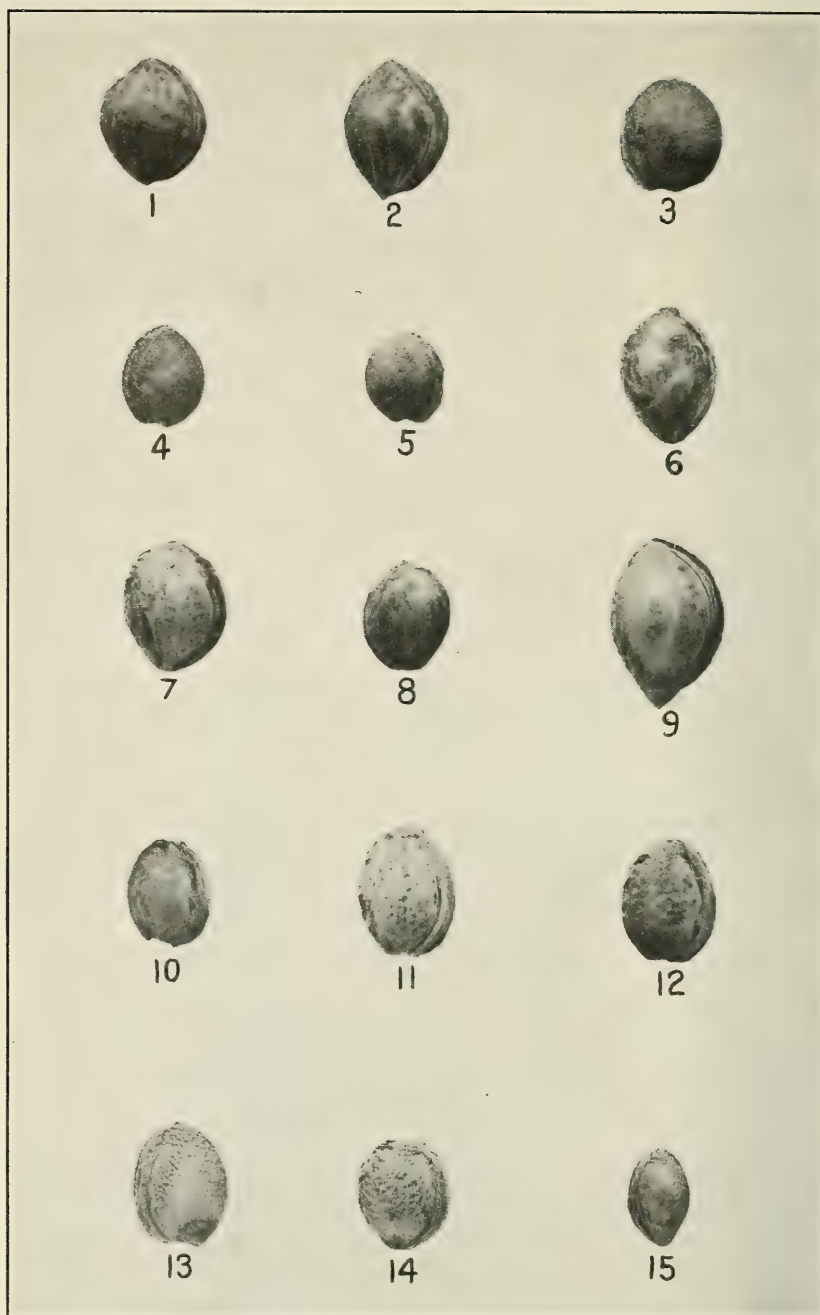
It was originally described from "near the mouth of the Columbia, and on subalpine hills, near the source of that river, Douglas; Fort Vancouver, Dr. Scouler." The specimens from near the source of the Columbia probably belong to the species. *Cerasus erecta* was described from Nootka Sound and from the description is plainly this form. *Cerasus pattoniana* was sent to the Muséum d'Histoire Naturelle, Paris, about 1865, by M. MacNab and is supposed to have come from northwest America, the exact locality being unknown; from the description and figure it is also this form. While *Prunus emarginata villosa* is quite unlike the species in habit and general appearance, it undoubtedly merges gradually with the species. More or less pubescent forms occur at various localities in California and in Arizona, but they are apparently of the smaller leaved, shrubby plant and are therefore referable to the species rather than to the subspecies.

This form has apparently not been utilized in pomology, but is sometimes planted as a shade tree and has been so used in Portland, Oreg.



STONES OF THE NATIVE AMERICAN SPECIES OF PRUNUS.—V.

FIGS. 1 to 3.—*P. alleghaniensis*: 1, From a tree in Huntingdon County, Pa.; 2 and 3, from Birmingham, Pa. FIGS. 4 to 6.—*P. alleghaniensis davisi*: From a tree in Montmorency County, Mich. FIGS. 7 to 13.—*P. umbellata*: 7 and 8, From Eustis, Lake County, Fla.; 9 and 10, from Jacksonville, Fla.; 11, from Athens, Ga.; 12, from Tavares, Lake County, Fla.; 13, from Marshall, Tex. FIGS. 14 to 17.—*P. maritima*: 14, From a tree in eastern Massachusetts; 15, from Atlantic City, N. J.; 16, from Cape May County, N. J.; 17, from Bucks County, Pa. FIGS. 18 and 19.—*P. gravesii*: From Groton, Conn. FIGS. 20 and 21.—*P. gracilis*: From near Denison, Tex. FIGS. 22 to 24.—*P. renulosa*: From near Denison, Tex. FIGS. 25 to 28.—*P. besseyi*: 25 and 26, Cultivated plant, Highland Park, Rochester, N. Y.; 27 and 28, wild plant, Custer County, Nebr. FIGS. 29 and 30.—*P. cuneata*: From Derry, N. H. FIGS. 31 to 34.—*P. pumila* (wild plants): 31, From Millers, Ind.; 32 and 33, from Saugatuck, Mich.; 34, from Minnesota. FIGS. 35 to 37.—*P. pennsylvanica*: From Saugatuck, Mich. FIGS. 38 to 40.—*P. emarginata*: From Oregon. (Natural size.)



STONES OF HYBRID VARIETIES OF PRUNUS.

FIG. 1.—*Prunus orthosepala*. FIGS. 2 to 15.—Hybrids: 2, Cultivated tree, Highland Park, Rochester, N. Y. (originally from Ellis, Kans.); 3, 4, and 5, Laire variety; 6, Surprise; 7 and 8, Hammer; 9, Ames; 10, *Prunus maritima* hybrid; 11 and 12, Marianna; 13, Six Weeks; 14, Maryland; 15, Compass. (Natural size.)

PRUNUS PUMILA L.

(Sand cherry.)

Prunus pumila L., 1767, Mant. Pl., p. 75.*Cerasus canadensis* Mill., 1768, Gard. Dict., ed. 8. (Not *Prunus canadensis* L.)*Cerasus glauca* Moench., 1794, Meth. Pl.; p. 672.*Prunus susquehanae* Willd., 1809, Enum. Hort. Berol., [t. 1], p. 519.*Prunus depressa* Pursh, 1814, Fl. Amer. Sept., v. 1, p. 332.*Prunus incana* Schweinitz, 1824, in Long Narr. Exped., v. 2, p. 387.

Leaves narrowly oblanceolate (Pl. VII, fig. 3), 3 to 7 cm. long, 1 to 2 cm. broad, cuneate toward the base, acute at the apex, usually serrate, with appressed teeth, at least above the middle, the serrations sometimes inconspicuous, glabrous on both surfaces and pale, or even with a glaucous appearance below; petioles 7 to 10 mm. long, eglandular or with one or two glands near the apex, or sometimes with glands on the base of the blade; stipules linear and glandular serrate. Flowers appearing with or before the leaves from the first of May to the middle of June, about 12 mm. broad, usually in clusters of 3; pedicels 9 to 10 mm. long, slender and glabrous; calyx glabrous, the tube campanulate, about 2.5 or 3 mm. long, the oblong, obtuse lobes as long as the tube or nearly so, minutely glandular on the margin; petals oblong-oval, narrowed to a short claw, about 6 mm. long. Fruit nearly black, without bloom, globose, and about 10 to 15 mm. in diameter, ripening in the latter part of July and in August, covering a period of four weeks or more, even in the same locality, usually not of good quality but occasionally palatable; stone ovoid (Pl. XII, figs. 31 to 34), usually rounded at the base, somewhat pointed or obtuse at the apex, varying from about 9 mm. long, 5.5 mm. broad, and 5 mm. thick to 11 mm. long, 7.5 mm. broad, and 7 mm. thick, slightly grooved on either side of the ventral edge, but without a prominent ridge or wing, rounded and minutely grooved on the dorsal edge, usually with a few rather obscure, oblique grooves branching from the dorsal groove.

Prunus pumila is a shrub $1\frac{1}{2}$ to 5 feet high, of willowlike habit, erect when young, the main stems later becoming more or less prostrate, but the growing branches erect; bark dark gray and marked with lighter-colored lenticels, the young twigs reddish, becoming dark reddish brown and finally gray.

Prunus pumila was originally described from Canada, and occurs (fig. 4) in gravelly or sandy or sometimes rocky localities along the shores of lakes or streams from eastern Quebec to Maryland, and westward to northern Indiana, eastern Minnesota, and the Lake of the Woods. It is especially abundant in the sand dunes along the shores of the Great Lakes, where it attains a much larger size than on the sandy plains of northern Michigan.

As yet apparently only one named variety of the species has been in cultivation, and it is probably of less value and has received less attention than its near relative, *Prunus besseyi*. The attention of horticulturists was called to the species many years ago. Andrew S. Fuller (25, p. 184) gives the following note, taken from his diary of 1846:

August 3, 1846, Thunder Bay Islands, Lake Huron.—Visited Hat Island, and found dwarf cherry (*Cerasus pumila*) very abundant, the plants growing on the beach in almost pure sand; bearing stems depressed with the weight of fruit; wonderfully productive. Fruit one-half inch long and three-eighths broad; dark purple, nearly black, sweet, but rather insipid; suckers abundant, from the underground stems or roots.

This is followed by a discussion of a form (*P. besseyi*) seeds of which he had received from Utah.

Prunus pumila appears to have been first described by Duhamel (19, p. 149) as a *Cerasus*, but without a binomial name, and it is also included by Miller in the 1759 edition of the Gardener's Dictionary. Miller says the seeds were sent to him from Paris, under the title of "Ragouminier," which was the name given them in Canada, where they were also called "Nega" or "Minel." The seeds were sent to Miller by Bernard de Jussieu, and were planted in the Chelsea Garden. The tree flowered in May, and the fruit, according to Miller, ripened in July. Linnæus, in the second edition of the Species Plantarum, erroneously quoted Duhamel's description under *Prunus canadensis* L.

PRUNUS PUMILA HYBRIDS.

Compass.—Leaves oblong or oblong-oval, 5 to 9 cm. long, 2.5 to 4 cm. broad, narrowed or rounded toward the base, acute or short acuminate at the apex, the margin conspicuously dentate with appressed rounded or glandular teeth, glabrous and dark green above, sparingly pubescent and pale below. Flowers appearing mostly before the leaves, about 18 mm. broad; pedicels about 6 mm. long; calyx tube campanulate, about 2 mm. long, equaled by the oblong lobes, the latter glandular and obscurely pubescent within or glabrous. Fruit dark red, nearly 2.5 cm. in diameter, ripening early in August; stone oval (Pl. XIII, fig. 15).

The originator (39; 40) of this hybrid writes as follows:

This new fruit, which was originated by me, is a cross (which I made in the spring of 1891) between the sand cherry (*Prunus pumila*) and the Miner plum. It is botanically called a cherry. Years ago I received plants of the sand cherry, native to eastern Minnesota, from J. S. Harris.

Flowers of the sand cherry were pollinated with pollen from the Danish Morello cherry and from the Miner plum. Stamens were removed from only one blossom of the sand cherry, and the fruit resulting from this flower appears to have been the only one to receive

attention. This seed was planted and came up in the spring of 1892, and the seedling fruited in 1894.

If the sand-cherry parent of this hybrid came from eastern Minnesota, as stated, it could scarcely be *Prunus besseyi*; as has been suggested (5, p. 244), since the latter does not appear to occur in the eastern part of the State, but would be either *P. pumila* or *P. cuneata*, and since the former is apparently the most common, it is perhaps the species concerned. The hybrid is of little value, so far as the fruit is concerned, but it is of interest as being apparently the first attempt at hybridizing the sand cherry. No doubt its success and publication and the hybrid of the western sand cherry with the sand plum, known as the Utah hybrid, has suggested to horticulturists the possibility of securing something of value for the Plains region from *P. besseyi*.

Rupert.—The variety Rupert is reported by W. T. Macoun to be a hybrid of *Prunus pumila* with *P. americana*.

PRUNUS CUNEATA Rafin.

Prunus cuneata Raf., 1820, Ann. Nat., p. 11.

Leaves broadly lanceolate (Pl. VII, fig. 4) or sometimes even obovate to elliptic or elliptic-obovate, 3.5 to 7 cm. long, 1 to 2.5 cm. broad, cuneate or gradually narrowed toward the base, obtuse or sometimes acute at the apex, usually serrate from below the middle or sometimes nearly to the base, green above and pale or even somewhat glaucouslike below; petioles 5 to 10 mm. long. Flowers and fruit similar to the preceding, but the stone usually slightly smaller (Pl. XII, figs. 29 and 30), being from 8 to 9 mm. long, 5.5 to 6.5 mm. broad, 5 mm. thick, and slightly pointed at the apex.

Prunus cuneata is an erect shrub, growing from 1 to 4 feet high, otherwise similar in habit to the preceding. It was first described from "the mountains of Pennsylvania," and occurs (fig. 4) sometimes in sandy, but more frequently in heavier soils, near lakes and about bogs, or other moist situations, from southern Maine and northern Vermont southward to the mountains of North Carolina and westward to Minnesota.

In flower, it is quite impossible always to distinguish *Prunus cuneata* in the herbarium from the preceding, but the young leaves are usually much broader in proportion to their length than in *P. pumila*, and they are nearly always strongly obtuse at the apex. Even mature foliage sometimes approaches *P. pumila* so closely as to render separation difficult, though they are usually much broader toward the base than in the former species. Nevertheless, the two appear to be well distinguished by habitual characters. It has apparently not been utilized in horticulture; and, being smaller, it is probably less promising than either *P. pumila* or *P. besseyi*.

PRUNUS BESSEYI Bailey.

(Western sand cherry.)

Prunus besseyi Bailey, 1894, N. Y. Cornell Agr. Exp. Sta. Bul. 70, p. 261.*Prunus pumila besseyi* Waugh, 1899, Vt. Agr. Exp. Sta. Rpt. 12, p. 239.*Prunus rosebudii* Reagan, 1907, in Ber. Deut. Bot. Ges., Jahrg. 25, Heft 6, p. 343.*Prunus prunella* Daniels, 1911, in Univ. Mo., Studies, Sci. Ser., v. 2, no. 2, p. 151.

Leaves oval-elliptic or oblong-obovate (Pl. VII, fig. 5), rarely narrower and oblanceolate, 3 to 4.5 cm. long, 9 to 15 mm. broad, cuneate toward the base, acute or rarely obtuse at the apex, sharply serrate from below the middle, glabrous on both surfaces; petiole 5 to 6 mm. long; stipules linear and glandular serrate or sometimes slightly lacinate. Flowers appearing with or before the leaves in the prairie region from the last of April to the middle of May or at higher altitudes probably somewhat later, 10 to 12 mm. broad, in clusters of 3 to 4; pedicels and calyx glabrous; pedicels 6 to 7 mm. long, glandular; petals oblong-oval, narrowed to a claw, about 6 mm. long. Fruit nearly black or varying to red and yellowish, nearly globular or somewhat oblong, 15 to 18 mm. in diameter, ripening in August and September; stone nearly globose to somewhat ovoid (Pl. XII, figs. 25 to 28) 7.5 to 10 mm. long, 6 to 8 mm. broad, 5.5 to 6.5 mm. thick, rounded or even slightly truncate at the base and obtuse or somewhat pointed at the apex, grooved on either side of the ventral and along the dorsal edge.

Prunus besseyi is a dwarf, bushy shrub, 1 to 4 feet high, erect or often more or less prostrate, sprouting from the roots, though not forming a dense growth or thicket.

Its distribution (fig. 4) includes South Dakota, where it was collected by Geyer in 1839 on the "hills of Missouri near the mouth of Shian¹ [Cheyenne] River," to Nebraska and Kansas and the eastern slope of the Rocky Mountains, in Colorado and Wyoming.

The western sand cherry is distinguished from *Prunus pumila* by its more bushy habit and broader leaves, from *P. cuneata* by its more pointed leaves, and from both these species by its leaves being shorter in proportion to their width and more prominently serrate, by the shorter petioles, and by its usually larger fruit.

It was introduced into cultivation in 1892 as the "Improved Dwarf Rocky Mountain," by Charles E. Pennock (2, p. 60; 3, p. 159), of Bellvue, Colo., who says he first saw this cherry in 1878 along the Cache la Poudre River, about 8 miles from his farm. It had been cultivated in the gardens in the same country, however, at least a few years earlier than its discovery by Mr. Pennock (2, p. 60) along

¹ Nicolle (57, p. 143). The name of this river is spelled Shayan, and there can be little doubt that it is the stream designated by Geyer "Shian." The specimen is in the herbarium of the Missouri Botanical Garden.

the stream named above. This species has been quite extensively experimented with at the Minnesota and South Dakota Agricultural Experiment Stations and in Wisconsin. E. S. Goff (27) used it as a dwarf stock for the peach, which, on this stock, attained a height of 5 feet. Writing many years earlier, A. S. Fuller (25, p. 184-185) says:

A few years ago, through the kindness of Prof. George Thurber, I received some cherry seeds from Utah Territory, and from them raised plants which appear to be of the same species * * * *P. pumila*. There is, however, considerable difference in the growth of the plants; the one grown from the seeds obtained from Utah being more erect, none of the branches trailing as in the species.

Discussing the question of crossing this species with the cultivated cherry, Mr. Fuller says:

Here is an opportunity for the enterprising and skillful horticulturist to revolutionize cherry culture, and he who first produces a fruit equal to the Great Bigarreau, or Early Richmond cherry, and borne upon a shrub no larger than a currant bush * * * will be very likely to gather golden harvests for his labor.

It seems rather doubtful that this species is really found wild in Utah. The only specimen seen from Utah was collected by Dr. Edward Palmer, probably in 1870, though the specimen is labeled 1869. Dr. Palmer, it appears, collected only in the vicinity of St. George, in the extreme southwestern part of the State, and while there he was the guest of Mr. Johnson, with whom the Utah hybrid is supposed to have originated. It is almost certain, therefore, that Dr. Palmer's specimen was from the garden of Mr. Johnson's former home. Recent collectors in the State do not find the species, and it is very improbable that it is found anywhere on the western slope of the Rocky Mountains. The seeds mentioned by Fuller as having been obtained by Prof. George Thurber in Utah may also have come from Mr. Johnson's garden. It does not appear that Dr. Thurber was ever in Utah, and the seeds were probably received by correspondence during the time he filled the chair of botany and horticulture at the Michigan Agricultural College or soon after assuming the editorship of the *American Agriculturist*, in 1863. It should be noted also that from 1850 to 1861 Utah Territory embraced the western portion of what is now the State of Colorado, and while *Prunus besseyi* is not known to occur even within that area, it does occur at not a great distance east of the old boundary, and seeds from such a locality may have been wrongly ascribed to Utah.

An original specimen of *Prunus prunella* has been seen, and it is only *P. besseyi* with well-marked leaf serrations. From the description *P. rosebudii* must also be this species.

PRUNUS BESSEYI HYBRIDS.

× *Prunus utahensis* ¹ Dieck., Koehne, 1893, Deut. Dendrol., p. 315.

Leaves oblong-oval to oval or rarely somewhat lanceolate in outline, slightly conduplicate, 3.5 to 5.5 cm. long, 1.5 to 2.5 cm. broad, gradually narrowed or sometimes rounded toward the base, acute at the apex, the margin crenate, the teeth gland tipped, glabrous on both surfaces; petioles 8 to 15 mm. long, pubescent along the upper edge or glabrous. Flowers appearing with the leaves, about 12 mm. broad; pedicels and calyx glabrous, pedicels about 8 mm. long; calyx tube about 2 mm. long; the oblong-ovate lobes as long as the tube, obscurely glandular; petals 6 to 7 mm. long. Fruit about 2.5 cm. in diameter, red, with a light bloom, poor in quality; stone similar in shape to that of *Prunus besseyi*.

This hybrid is an irregularly branched shrub 3 feet or more in height, showing some of the characters of both of its supposed parents, *Prunus besseyi* and *P. angustifolia watsoni*. It has also been crossed with *P. americana*. (Pl. XIII, fig. 14, Maryland).

The variety *Montbesseyi* is supposed to be a hybrid between the Montmorency cherry (*Prunus cerasus*) and *P. besseyi*. The leaves approach the size and form of *P. cerasus* very closely, but the flowers have not been examined.

In addition to the above hybrids, N. E. Hansen (30, p. 173, 192) has described a number of others reported as crosses with *Prunus americana*, *P. simonii*, *P. cerasifera atropurpurea*, *P. triflora*, *P. armeniaca*, and *Amygdalus persica*. Mr. Hansen writes that the hybrid with the last-named species is sterile.

The earlier hybrids produced do not appear to possess much merit; nevertheless, this field must be considered as offering some possibilities, and crosses between the best forms of *Prunus besseyi* and the variety known as "Laire," described under *P. orthosepala*, might afford a better fruit than the Utah hybrid.

NAMES PUBLISHED IN SYNONYMY OR ACCOMPANIED ONLY BY UNIDENTIFIABLE DESCRIPTIONS.

Prunus acinaria Desf., 1804, Tabl. Ecol. Bot. Mus., p. 179.

Name given without description, North America.

Prunus acuminata Hort., K. Koch, 1869, Dendrol., t. 1, p. 101.

Only incidental mention of horticultural material referred by Koch to *Prunus americana*.

Prunus californica Hort.

Cited by Koehne, 1893, Deuts. Dendrol., p. 312, as a synonym of *P. acuminata*. "Wildenow (ob auch Michaux?)." The plant de-

¹ For an account of the origin of this form, see Bailey, L. H. (4, p. 262, 265; 5, p. 244, 247).

scribed by Koehne under the latter name is *P. americana*, but since the name *P. californica* is given only in synonymy it is not a valid publication.

Prunus coccinea Raf., 1817, Fl. Ludov., p. 135.

Rafinesque's description was based on the following description by Bartram (9, p. 421):

* * * Plumbs, &c.; of the last mentioned genus, there is a native species grows in this island, which produces its large oblong crimson fruit in prodigious abundance; the fruit, though of a most enticing appearance, is rather too tart, yet agreeable eating, at sultry noon, in this burning climate; it affords a most delicious and reviving marmalade, when preserved in sugar, and makes excellent tarts; the tree grows about twelve feet high, the top spreading, the branches spiny and the leaves broad, nervous, serrated, and terminating with a subulated point.

This plum was observed on Pearl Island, La., probably between August 5 and 27, and could therefore scarcely have been *Prunus angustifolia*. In the fall of 1910 S. M. Tracy made a trip to Pearl Island, but found no *Prunus*, and he has since learned from those living in the vicinity that there have been no plum trees on the island within the past 40 years. About 25 or 30 years ago, however, a single wild tree, which has since died, was known on Isle au Pois on the east bank of Pearl River. In Bartram's time these trees may have been more abundant.

Prunus declinata Marsh., 1785, Arb. Amer., p. 112, "Dwarf plumb."

Marshall describes this as follows:

This is of a small dwarfish growth, seldom rising above 4 feet high, but frequently bearing fruit at the height of 2 or 3, which is small and almost black when ripe.

Although sometimes cited as a synonym of *Prunus maritima*, the fact that the beach plum was known to Marshall and that his description of *P. declinata* is quite as applicable to *P. pumila* renders the usual disposition of Marshall's name somewhat doubtful.

Prunus floribunda Hort., K. Koch, 1869, Dendrol., t. 1, p. 119.

Cited as a garden name for *P. pumila*.

✓ *Prunus hortulana robusta* Waugh, 1901, in Vt. Agr. Exp. Sta. Rpt. 14, 1900/01, p. 277.

This name was proposed by Waugh for a group of *Prunus triflora* hybrids which he designated the Gonzales group, and of which he considered the variety Gonzales the type. To this group he referred 30 varieties, hybrids (so far as the parentage is known) of *P. triflora* with *P. angustifolia*, *P. angustifolia varians*, *P. munsoniana*, and *P. hortulana*. Waugh's application of the name *hortulana* was not in its original usage, but to the Wild Goose group, *P. munsoniana*, while the variety Gonzales, although its parentage is not definitely

known, appears to be a hybrid of *P. triflora* with *P. angustifolia* *varians*.

Prunus mississippi Marsh., 1785, Arb. Amer., p. 112. "Crimson plumb."

Marshall's description of this species does not admit of identification. He says:

This grows naturally upon the Mississippi and is of larger size than most of the other kinds. The fruits are crimson colored and somewhat acid.

Prunus tawakonia Lindh., Gray, 1850, in Boston Jour. Nat. Hist., v. 6, p. 186.

Given only as a synonym of *P. rivularis*.

Prunus triflora. Raf., 1820, Ann. Nat., p. 11.

Rafinesque's description of this is as follows:

Arborescent, branches crooked and smooth, leaves subsessile, oblong lanceolate, acuminate, crenate, subobtus; umbels sessile, commonly triflora; calyx acute, petals erose. A tree 20 feet high, probably a cherry tree. In the mountains of Pennsylvania. Flowers numerous, white, smelling strongly of honey.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE



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Contribution from the Bureau of Soils, Milton Whitney, Chief.
April 16, 1915.

SOIL EROSION IN THE SOUTH.

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The study of eroding soils has been undertaken to determine if possible from both a field and laboratory examination the factors influencing erosion and the means applicable for its prevention or correction. A field trip involving this study was made through the States of Virginia, Tennessee, Missouri, Mississippi, Alabama, Georgia, South Carolina, and North Carolina. Observations were made on the nature of erosion, the effects produced by erosion, remedies applicable or in use, differences in forest or field, the topography and drainage, the nature of the soils and subsoils, and on such agricultural problems as terracing, crop rotation, seeding for pasture, labor, and economic conditions. In this paper are discussed the conditions affecting soil erosion as observed in the field. A study of the important soils is being made in the laboratory and a subsequent paper will deal with their physical characteristics and properties.

EROSION AS RELATED TO THE FORMATION OF SOILS.

It is necessary at the outset to understand something of the methods of soil formation and the causes producing soils. The two large classes of soils, according to the processes by which the soils material has been accumulated, are those derived from material accumulated by disintegration and decomposition of the rock in place, or residual soils, and those derived from material accumulated by deposition from wind, water, or ice.

RESIDUAL SOILS.

The accumulation of soil material through the disintegration and decomposition of rock material in place is effected by a number of forces both mechanical and chemical in their nature. The most important mechanical process and the only one worthy of mention

NOTE—This bulletin is of general interest, but especially in Virginia, Tennessee, Missouri, Mississippi, Alabama, Georgia, South Carolina, and North Carolina.

here is the expansion of the rock material due to changes in temperatures, including the expansion of the water contained in the rock at the freezing point. The most important chemical process is solution, while oxidation and hydration are of great importance.

The layer of resulting material mixed with some organic matter and capable of supporting plant life is known as soil. Its composition does not differ very markedly from the rocks from which it is derived. At best this process of accumulation is slow, the rate depending somewhat on the activity of the agencies producing it.

TRANSPORTED SOILS.

Soil materials formed in one place and deposited in another through the agency of wind, water, or ice constitute or develop into transported soils. These, however, are not the eroding soils, but are the results of soil erosion.

TRANSLOCATION OF SOILS BY WATER.

The movement of soil material by water is limited by two inherent properties. Water can move only from a higher to a lower level, and it can affect only the surface with which it comes in actual contact.

Since water moves over the surface of the soil only under the force of gravity, its action is always directed toward moving material from the hills and depositing it in the plains. If a stream is arrested in its movement down hill by the construction of an impediment, such as a dam, it produces a lake which acts as a settling basin. The stream gives up its burden of detritus and the lake is gradually filled. Eventually this results in the bottom of the lake reaching the level of the dam, when the stream will then carry its burden to some lower lake or to the ocean and deposit it.

Streams can erode only those surfaces over which they flow, and this greatly restricts their power in this respect. Thus the larger part of the detritus of streams must be derived from the surface drainage of adjoining areas. Here the amount of surface drainage is dependent on the absorptive power of the soil and on its drainage. If the soil is more or less loose and porous its absorptive capacity is high, so that it may absorb rain as rapidly as it falls unless the precipitation be extraordinarily heavy. On the other hand, if the soil is close grained and compact the absorption is slow, even though the actual pore space within the soil be greater than in the case of the loose soil. In case of a gentle rain, absorption may be rapid enough to prevent surface drainage, but with any heavy and rapid rainfall the water runs off largely from the surface.

WATER-TRANSPORTED MATERIAL.

Physics.—The excess of water draining from the surface of a soil carries with it some of the material in suspension. The existing val-

leys are built up by the deposition of such material brought down from the hills, and new valleys are formed by the gradual enlargement of gullies on the hillsides.

The size of the material moved by running water varies from the finest material to the large boulders rolled along the beds of swiftly flowing streams. The amount of material that any particular stream of water can carry in suspension is limited, and if that limit is reached no more material can be picked up as long as the velocity of the stream and the size of particles in contact with it remain the same.

The size of particles which can be carried in suspension by the water depends on the surface-mass ratio of the particles and on the velocity of the water. A discussion of the relation of the carrying power of water to suspended material leads to consideration of the special subject of suspensions or of disperse systems of matter.

It has been repeatedly stated that the slope affects erosion to such an extent that doubling the slope increases the erosive action four times, and that doubling the velocity of a stream increases its transporting power sixty-four times. Gilbert¹ has recently pointed out that these statements are slightly erroneous. Instead of the quantity of material moved varying with the sixth power of the velocity, it varies nearly as the fifth power.² However, the maximum size of grain or pebble that a stream is competent to move varies as the sixth power.

The factors which modify the capacity of a stream to transport debris along its bed are many. Width of stream and velocity of the water are factors. Both slope and depth affect velocity, and in turn depth is affected by discharge and slope. Size of material transported is an important factor, as much greater weight of fine than of coarse material may be carried. The shape and density of the material are also factors influencing the transportation. The course which the stream follows also exerts an influence, the carrying efficiency being affected by turns and curves. The viscosity of the water, varying with the temperature, the friction against the banks, and the nature of the dissolved or suspended material are factors. The interaction of these factors on one another makes the problem more difficult to study. It is most important to note that the transporting power is influenced most by the change in velocity.

The first action of the fallen drops of water as they collect is to carry with them some of the finest material, or the clay particles. As the streamlets grow, greater volume causes increased velocity and a transporting power increasing to such an extent that larger and larger particles are carried along in suspension or rolled along

¹ G. K. Gilbert, U. S. Geol. Survey, Prof. Paper 86 (1914).

² Deacon, G. F., Inst. Civil Eng., Proc. 98, (1914).

the stream bed. Where the velocity is greatest, generally midway between the crest and the foot of the hill, the erosion is greatest.

The modes of transportation as determined by experiment¹ show that some of the particles carried by a stream slide along, some roll, and many make short leaps, the process being called "saltation." Saltation itself grades into suspension. In saltation the particles are just on the verge of suspension; a slight difference in one of the factors may cause the particles to remain in suspension.

At the foot of the hill, where the slope becomes less steep, there is a deposition of the coarser material. The gravel and sand are deposited first, the silt next, and the clay particles last. The quantity of coarse material carried by a stream is greatest in times of floods, while during periods of normal flow the silt and clay particles greatly predominate. The smaller particles are carried in suspension until the plains are reached, or are transported to the sea.

SOURCE AND QUANTITY OF MATERIAL.

The source of the material transported by water is in the hills. The streams may deposit it at one place, later to take it up and move it to another; but this is only a part of the process of bringing the soil from the uplands and depositing it in the lowlands. A detailed discussion of the factors affecting sedimentary formations is given by Mather.²

The quantity of soil material moved during one year by the streams of the United States is very large. The great depths to which some of our rivers have cut represent the ultimate effect of the removal of soil material by the action of water. The Columbia River and the Colorado River have cut gorges to depths of 2,000 and 5,000 feet, respectively. Under more favorable conditions, where the soil is loose or incoherent, the action may be even more marked. The quantity of material carried in suspension to the sea by the Mississippi River, which drains over one-third of the area of the United States, has been variously estimated at 370,000,000 tons³ to 680,000,000 tons⁴ per annum. The total amount of soil material carried to the sea annually by the rivers of the United States is estimated by Dole and Stabler⁵ as 783,000,000 tons. Estimates of the United States Geological Survey place the quantity of material carried in suspension annually by the Hudson River at 240,000 tons; by the Susquehanna, 240,000 tons; by the Missouri above Ruegg,

¹ C. K. Gilbert and E. C. Murphy, U. S. Geol. Survey, Prof. Paper 86 (1914); Jour. Wash. Acad. Sci., 4, 154 (1914).

² W. W. Mather, Physical Geography of the United States East of the Rocky Mountains; Am. Jour. Sci., 49, 14284 (1845).

³ Humphrey and Abbott, Surveys of the Mississippi.

⁴ Dole and Stabler, U. S. G. S., Water Supply Paper 234, 84 (1909).

⁵ Bul. Geol. Soc. Am., 2, 130 (1894).

near its confluence with the Mississippi, 176,000,000 tons, with corresponding amounts carried by various other rivers. Enormous as these figures are, they do not represent by any means the total losses from the soils drained by the streams. No estimates of the total amount of material actually moved through the agency of water has been made, but it must be many times greater than the amount which reaches the sea in suspension.

A case is reported by Tarr¹ describing the intense action of a flood in an arroyo in the Rio Grande Valley, New Mexico, due to a local cloudburst in the Donna Ana Mountains of about half an hour duration and extending over an area of less than 6 square miles. Such large quantities of material were brought down from the hills that several acres were covered with silt and gravel. An adobe house about 10 feet high was buried to within 2 feet of the top. Several thousand tons of earth must have been transported during this sudden rush of water. Tolman² describes the transporting of material by streams of the arid region. The quantities of sand being carried to the sea are discussed by Marsh.³ In addition to the solid particles carried to the sea by the streams, the quantity of dissolved material is also enormous. It is estimated that the Mississippi River carries annually to the Gulf of Mexico 86 tons of dissolved salts from every square mile drained by it. The rivers of the West carry much larger quantities than this.

MOVEMENT OF SOIL MATERIAL BY THE WIND.

The total amount of soil material moved by water is large, a fact well known, but the fact that almost equally as large amounts are moved through the agency of the wind is not generally appreciated. The wind exerts its action in any direction or in any climate. While it is true that the greatest effect is shown in arid or semiarid regions, the wind of the humid regions always carries a burden of suspended soil material. The dry material of an arid climate is more easily moved, and hence the greater effect produced.

In considering the transporting capacity of wind, Free⁴ has estimated from experiments by Udden⁵ that the capacity of winds blowing over the Mississippi basin is probably at least a thousand times as great as the transporting capacity of the river. The wind, however, is usually loaded to only a small fraction of its capacity, so that the amount of material transported is very much less than its capacity. It is certain that the quantities actually moved by the wind are very large, and this movement contributes much to the change of soil surface conditions.

¹ Tarr, *Am. Naturalist*, **24**, 456 (1890).

² Tolman, *Jour. Geol.*, **17**, 142 (1909).

³ Marsh, *The Earth as Modified by Human Action*, Ed. 1888, p. 528.

⁴ E. E. Free, *Bureau of Soils Bull.* No. 68, p. 46 (1911).

⁵ *Jour. Geol.*, **2**, 326 (1894).

EXCESSIVE TRANSLOCATION OF SOIL MATERIAL.

The methods of translocating soil material either by wind or water have played important parts in the geologic history of the earth. The complex relations between topography, climate and erosion, and transportation and sedimentation can not be discussed in a paper of this character, but these relations are clearly brought out in articles by Joseph Barrell.¹

It is not with this movement of material in its natural condition that we are especially concerned, but with conditions in which man has for some purpose, either for agriculture, lumbering, mining, or power, interfered with the natural process, so that an excessive removal of soil material results. Since it is necessary to follow the vocations that disturb the balance established by nature between rainfall, slope, and erosion, methods of minimizing this disturbance as much as possible should be determined and employed.

CAUSES OF EROSION.

Erosion of land surface is produced by water flowing over its surface or by wind action. Wind erosion has been studied and described by Free and the general principles underlying soil erosion by water have been described by McGee,² so that only a short statement is here necessary. In the South it is of course the action of water that plays the more important part in soil translocation.

Water reaching the surface of the soil either sinks into the soil, evaporates, or runs off the surface. That portion which evaporates enters into the formation of clouds and is later returned to the earth; the portion that sinks into the ground increases the underground store of water, a part of it reaching the streams and wells by seepage and a part being returned through capillary action to the surface, where it may be utilized in the growth of plants, or may join the evaporated portion. This downward movement into the soil causes a slight movement of particles, resulting in the alteration of the mechanical composition of the soils and subsoils,³ but this is small in comparison to the movement of soil material by the water which runs off the surface. It is this water which lifts and carries along soil material, cutting into the soil surface and leaving it bare and gullied.

The water running off the surface of the soil has been estimated in a number of cases. The Illinois experiment station⁴ reports that 48.9 per cent of the rain falling in the Savannah River basin reaches the sea. Of the rain falling in the Potomac drainage basin it is esti-

¹ Jour. Geol., **16**, 159, 255 and 363 (1908).

² W J McGee, Soil Erosion, Bul. No. 71, Bu. of Soils, U. S. Dept. of Agr. (1911).

³ Davis and Fletcher; Distribution of Silt and Clay Particles in Soils. 8th Internat. Cong. of App. Chem., **15**, 81 (1912).

⁴ Ill. Expt. Sta. Circ. No. 119 (1908).

mated that 53 per cent reaches the sea. When the mean annual rainfall on mountain topography is 40 inches, the run-off approaches 30 inches; if the rainfall is 25 inches, the run-off is about 12 inches; and if there is 15 inches rainfall, the run-off is less than 5 inches.

All effort should be directed toward lessening the surface run-off and increasing the quantity of water soaking into the soil. If all the water falling on the surface of a given area were absorbed by the soil, there could be no erosion. It is the water flowing over the surface that must be controlled to prevent damage from excessive soil washing.

The amount of water which the ground absorbs depends upon the slope, the character or condition of the soil, the nature and amount of vegetal covering, and the amount and character of precipitation. Perhaps the slope has the greatest influence of any of these factors, but even this may be more than balanced by the character of soil, the precipitation, and the vegetation. As has been previously pointed out doubling the slope results per se in greatly increasing the erosion, but the increased velocity of water flowing down the slope makes the erosive power about 32 times greater.

The character of a soil greatly influences the amount of water absorbed by it. Soils vary in composition from light or sandy soils to heavy or clayey soils. The difference is in the size of particles composing them. The loams lie between the two extremes and represent varying mixtures of the coarser and finer particles of soil. While it is true that the actual pore space in a clay soil is much greater than that in a sandy one, the size of the individual spaces is much smaller in the case of the clay, so that the movement of water within the clay is slower than in the sandy soil. The sandy soils, therefore, absorb rainfall more readily than the heavier soils. The power of a soil to absorb water rapidly depends not so much upon the total amount of pore space as upon the size of the individual spaces. Of course, the absorptive capacity should be such that all of the interspaces are not filled by the rainfall at any particular time. The size of the interspaces may be increased in the heavier soils by the introduction or incorporation of organic matter. Upon moderately rolling land the following classification shows the relative capacity of the soils for absorbing an ordinary rainfall:

Class.	Composition. ¹	Amount of water absorbed.
Sands.....	Less than 20 per cent silt and clay; 25 to 50 per cent sand.	Nearly all.
Sandy loams.....	20 to 50 per cent silt and clay, 25 to 50 per cent sand.	Large part.
Loams, silts, and clay loams...	50 per cent silt and clay, less than 30 per cent clay.	Very little absorbed.

¹ From values given by Whitney, Bul. 78, Bureau of Soils, U. S. Dept. Agr., p. 12.

This classification holds for only very limited conditions. It shows the relative absorptive power of the soils named, other conditions being the same.

The depth of the soil is the ultimate measure of the amount of water it is capable of absorbing. When the soil is saturated the additional water falling on it runs off over its surface, carrying away soil particles. A thin layer of soil, underlain at shallow depths by an impervious layer, becomes saturated quickly and erosion at the surface is most active. The depth of plowing in cultivated areas has much to do with the depth of the soil and the amount of water necessary to saturate it.

Vegetation affects the amount of water absorbed by the soil by retaining the water for a longer time on the surface, giving it a better opportunity to be absorbed. An additional effect is that the soil is kept more or less open by the roots penetrating it, and these roots form channels along which the water may be conducted to the subsoil. The vegetation further affords protection to the soil in that it retards the movement of the water flowing over the surface and prevents the removal of soil particles.

All these factors influencing the absorption of water by the soil are under the control of man, with the single exception of the precipitation. However, this factor is fairly constant as to quantity, although slightly less so as to character, for any given locality. If 2 or more inches of rain fall during 24 hours, much of it will be absorbed by the soil, but if the same amount of rain falls during 1 or 2 hours, only a small part will be absorbed. Since the movement of water within the soil meets with considerable frictional resistance, this movement is rather slow. If the water moves into the lower layers at a rate slower than that at which water is furnished to the surface, the upper layer of soil soon becomes saturated and the additional water runs off over the surface. Again, if precipitation occurs in the form of rain, it is much less likely to be totally absorbed than if in the form of snow. The melting snow supplies water to the soil so gradually that it has ample time to be totally absorbed.

In the Southern States probably the most important factor influencing absorption is the character of the precipitation. This is mainly in the form of rain and is quite heavy at times. This means that generally this factor is most unfavorable for the retention of water by the soil and to prevent its flowing off the other factors must be made as favorable as possible. In the mountainous regions of Virginia, North Carolina, South Carolina, and Tennessee vegetation exerts great influence. Where the forests have been cut off the steep hillsides rapid erosion has followed, and in some places the soil has been removed down to the underlying bare rock. Other



TREES IN GULLY, CHECKING EROSION AND TENDING TO NATURAL RECLAMATION.

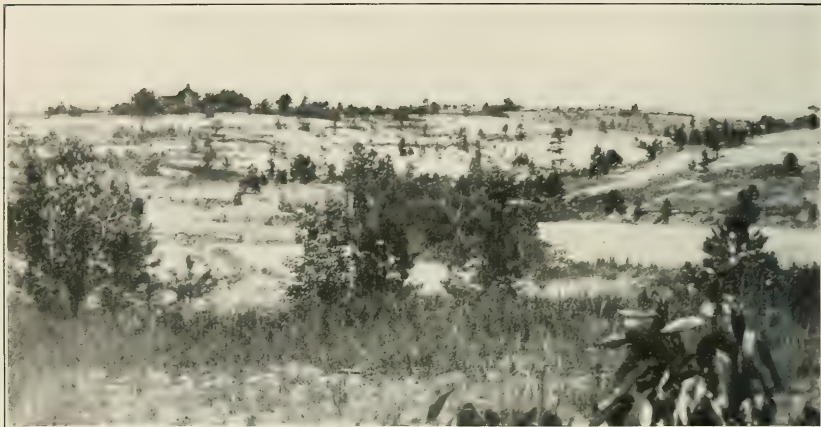


FIG. 1.—NATURAL RECLAMATION BY GROWTH OF SHRUBS AND PINES ON ERODED LAND.



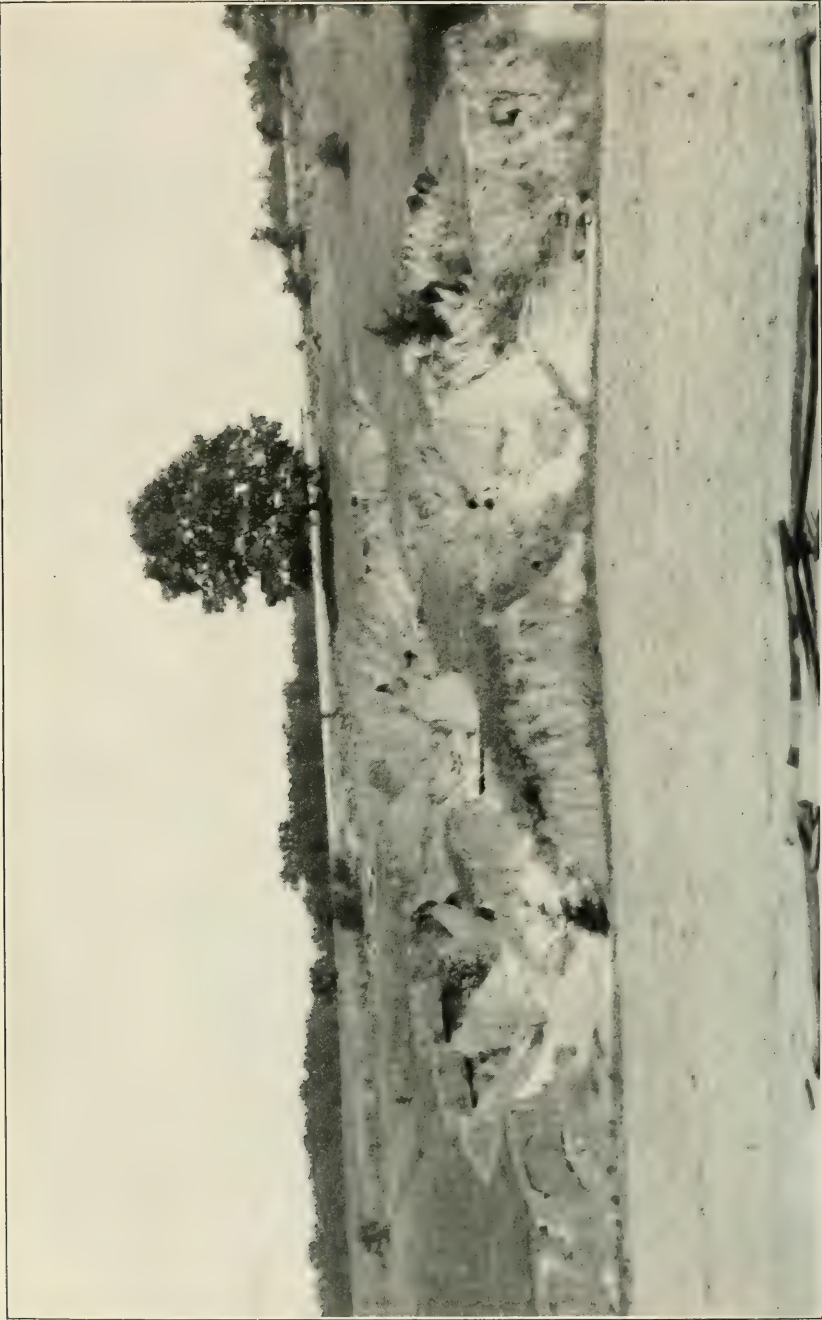
FIG. 2.—NATURAL RECLAMATION BY VOLUNTEER GROWTH.



FIG. 1.—GULLY WITH SLOPING SIDES AND ROUNDED EDGES.



FIG. 2.—GULLY WITH VERTICAL SIDES AND CAVING BANKS.



SURFACE CLAY UNDERLAIN BY SANDY SUBSTRATUM.

localities, which will be described later, show the predominating influence of some other factor.

THE NATURE OF EROSION.

The erosion of the soil occurs mainly in two ways which are markedly different (1) as sheet erosion and (2) as the gully type of erosion. In sheet erosion the water falling on the surface of the soil carries off with it a small amount of soil material from every part of the field. In advanced stages there appear incipient gullies, parallel to each other, known as shoestring gullies. This type of erosion is not so destructive of the field on which it occurs as the gully type, for the removal is more uniform and, if a field is continually cultivated the physical evidence of erosion may be slight. A common result is the occurrence of a rounded knoll showing a difference in the character of the soil on the top and at the base, and often this difference extends to a difference in productiveness, the top of the knoll being less productive than the base. This type of erosion in advanced stages develops gullies with sloping sides and rounded edges. It is often spoken of as old-field erosion of parallel gully type.

The region in western Virginia extending to the Tennessee line commonly erodes in this manner. In some sections the soil wash is not serious enough to interfere with the cultivation of rather steep hillsides without contouring or terracing. However, on bare fields which remain out of cultivation for a few years, the gullies form and grow to considerable size. In eastern Tennessee the washing of the soil is somewhat greater, but here, even in the hills, terraces are hardly known. This same sort of erosion occurs in the Appalachian region of North Carolina and South Carolina and in northern Georgia and Alabama, but in the last-named States the formation of gullies is more rapid and the destruction greater.

The second type of erosion, or the gullying, develops where, owing to the occurrence of natural depressions, the water runs off in the form of streams. These cut into the soil and soon develop gulches of great depth with nearly vertical sides, which grow in length, breadth, and depth with every rain. This type of erosion is the most difficult to check, and renders the land on which it occurs practically valueless.

RESULTS OF EROSION.

Excessive erosion results in a change in the physical condition of the soil. As already pointed out, the bodily removal of soil particles takes place from the surface. There is a sorting of the soil particles, the larger and heavier being deposited first and the smallest last. The result is an impaired physical condition of the soil wherever this sort-

ing action is taking place. Soils composed almost entirely of either sand or clay particles are not so good as those with a fair amount of each.

The quality of the soil is greatly impaired by the continual process of erosion. Rapid leaching takes place, removing a large part of the soluble salts; the surface soil is often washed down to the lowlands and sometimes out to the sea; gullying so defaces the land that it becomes difficult to cultivate. The organic matter is one of the first losses of eroded soils. Abandonment of the field follows, because the land is considered too poor for agricultural use, having lost its productiveness through the process of erosion.

The gullies in a field act as drainage ditches. The land between such gullies drains too rapidly, the water-table is lowered, and it is difficult for the crops to obtain sufficient water for proper growth or to withstand even a moderate period of drought. As these gullies occur on hillsides, the natural drainage is ample, if not excessive, so that the additional drainage furnished by the gullies is a positive disadvantage.

This removal of the best soil material and the impairment of that remaining results in the occurrence of much waste land. In the South the abandonment of land is traceable more often to erosion than to any other cause. In some of the States vast areas amounting occasionally to 50 per cent of the arable land of those sections have been abandoned to the ravages of water wash.

THE PREVENTION OF EROSION.

The necessity for the prevention of erosion is obvious. There is every indication that the public conscience is being quickened in this respect, and several States are beginning to appreciate the necessity of conserving their soil. The State of Tennessee is making a serious effort in this direction. The State geologist, with the aid of soil and forestry experts, is waging a campaign of education to teach the farmers how to prevent erosion and reclaim eroded lands. Some of these lands with proper care can be reclaimed for agricultural use, while others can be utilized for forestry. It is the function of the experts to determine the best use of eroded lands in various sections of the State.

A number of papers on the subject of erosion and its prevention¹ point out the damage from erosion and the general means of controlling it.

METHODS OF PREVENTION.

Methods employed for the prevention of erosion must embody either one or two principles: They must increase the capacity of the soil for absorbing water or must decrease the velocity of the running

¹ Farmers' Bul. No. 20, U. S. Dept. Agr.; Ill. Expt. Sta. Cir. No. 199; Soil Rept. No. 3, Ill. Expt. Sta.

water. The most effective methods make use of both principles. The porosity of the soil may be increased by the incorporation of organic matter and by breaking the soil to considerable depth. Deep plowing alone is not so beneficial as when used in conjunction with the incorporation of organic matter in the soil. The organic matter promotes a granulation of the soil particles and thus produces a soil with larger spaces between the soil granules. The rate of absorption is greatly increased and the storage capacity enlarged.

Tillage operations which move the soil to considerable depth tend to lessen erosion. They furnish a larger reservoir for the reception and retention of water. Preliminary experiments in this laboratory indicate that the dust mulch may have no advantage and is, possibly, a positive disadvantage. The fine particles of dust, when subjected to a sudden shower, are beaten into a thin layer of puddled soil on the surface which prevents rapid absorption and allows water to flow off the surface of the soil.

The methods that decrease the velocity of the running water are those in which impediments are placed in the path of the run-off. For every given velocity of running water there is a maximum amount of material that can be carried in suspension, and this amount increases with the velocity. If, then, flowing water carrying its maximum load has its velocity reduced it becomes overloaded and must deposit part of the load. If the velocity remains low the carrying power of the water is small. With the methods intended to check the velocity of the water belong the construction of various forms of terraces and the growth of vegetation or the placing of any impediments in the path of the water.

LAYING OFF TERRACES.

Terraces, no matter of what kind, should be laid off level or nearly so. The most common way is to use a leveling instrument and a rod with target attached. In laying off the terrace, the instrument is set on the highest part of the land and the bubble brought to the middle of its tube. The rod is placed by the level and the target moved to a height 3 feet above the line of sight. The rod should then be moved downhill until the target is in the line of sight. The bottom of the rod will then be 3 feet below the position of the level. Other points at the same level, 10 or 15 paces apart, should be located and through these points the terraces constructed. After the line of one terrace is located, the level may be set upon one of the points marked, proceeding as before. The terrace lines will then follow the contour of the hills. If slight depressions occur between two points, it is best not to change the terrace line, but to fill in the depression. Instead of using a level, good results may be obtained with an imple-

ment known as an A, which does not require any special skill in operating.¹

KINDS OF TERRACES.

There are several kinds of terraces in use, such as the guide row, the level bench, and the Mangum terrace. The guide-row terrace is formed by throwing four furrows together along the contour line of a hill, the furrows following the line of the guide row. A row may be planted on top of the terrace to avoid the waste of any land. There is generally a drop of 3 feet between terrace rows. This type of terracing is used on rather open soil which will readily absorb the rainfall, and where the slope does not exceed 10 per cent.

The level-bench terrace is constructed on steeper lands and is so cultivated that the soil is moved from the higher to lower portions. In this way the terrace becomes practically level in a few years. By plowing with a hillside plow the furrows may all be thrown down hill. Quite often this type is developed from the guide-row terrace. Each bench must be cultivated separately and farm machinery or wagons must not be driven across the terraces, as this will result in their quick destruction by forming trenches which develop into gullies. Care should be exercised to prevent the growth of weeds along the terrace lines, though the presence of grass is often necessary to hold the soil. The cultivation may be done in furrows following the contour, or furrows may be run straight. This latter method results in some short rows, to which many farmers object. Probably the best method to prevent erosion is to follow the contour.

The Mangum terrace is one that has attracted considerable attention lately because of the fact that it eliminates the uncultivated lines between the terraces and cultivating or harvesting machinery may be driven across from one terrace to another. This terrace was first constructed and developed by Mr. P. H. Mangum, of Wake County,

¹ Any frame in the shape of an A will do. The legs must have the same length and the crosspiece must be at equal distances from the ends of the legs. A plumb bob with string attached to the top of the A completes the apparatus.

The center of the crosspiece should be determined, as the A will be in a level position when the line of the plumb bob passes through the center of the crossbar.

In laying off a terrace, one leg of the A is held on a point and the other revolved about it until the plumb line crosses the point marking the center of the crossbar. This process is continued from point to point.

By constructing the A with certain dimensions, it may be used also for determining the grade or slope of a field or roadway. The sides are 16 feet long and the crossbar 13 feet 9 inches. A brace 16 feet long may be attached by a leather hinge. The ends of the A will then be 16 feet 8 inches apart when set up.

To use in determining grade, find the center of the crossbar and mark it zero. Then drive two pegs in the ground 16 feet 8 inches apart and on a level and set the A on them. The plumb line crosses at zero. Raise one end 2 inches and mark where the plumb line crosses the arm 1 per cent. Raise the same end 2 inches more and mark 2 per cent on the arm, and continue until the one leg has been raised several feet. Then repeat the operation on the other side. After the crossbar has been marked, if the A is placed on any slope, the plumb line will indicate the grade. The low side of the bar may be marked 2 inches, 4 inches, etc., corresponding to 1 per cent, 2 per cent, etc. A 3-foot fall between terraces may be obtained by moving one leg of the A downhill until the plumb bob reading is 36 inches. To obtain differences in elevation between two points, run over the line, keeping records of the plumb-line reading, all values going downhill in one column and uphill in another. Add the two columns and the difference between the sums will give the difference in elevation of the two points.

N. C. It differs from the others in that the terrace lines are not level, but contour the field at a grade of $1\frac{1}{2}$ inches to 14 feet. This terrace is a broad bank of earth with gently sloping sides. It is constructed along the lines laid off by back furrowing and pulling the soil to this line, thus forming a low dike. This terrace has been described in detail in a Government publication.¹ It gives a gradually sloping side both above and below its highest point, so that cultivation may be carried on across the ridge in any direction. While providing protection to the land it also eliminates the waste land and breeding places for insects afforded by the weeds or grass growing on the terrace ridges. For most agricultural lands it is the ideal terrace, but it may not be suitable for some soils of a light character.

OTHER METHODS OF PREVENTION.

In addition to the use of terraces to prevent washing of the soil it is generally advisable to plow deeply. By plowing deeply the soil is so loosened that the rate of absorption becomes much greater and the land is enabled to take care of a heavier sudden rainfall. The same thing is accomplished by incorporating organic matter in the soil or by use of tile drains. In fact, any method that will assist in the efficient drainage of a soil will also do much toward the prevention of excessive erosion. The interstitial spaces become larger in a well-drained soil, so that the movement of water through the soil is more rapid. Hence a heavy precipitation may be absorbed as rapidly as it falls.

Prevention of erosion is accomplished by having some vegetation cover the entire surface of the soil. This offers resistance to the water flowing over the surface and retains it long enough for the soil to absorb larger quantities than would be possible under clean culture. The expedient of alternating strips of cultivated soil with grass strips is sometimes resorted to, and on moderately rolling land this is fairly effective. Again, land that would be unsuitable to clean culture may be utilized for orchards with a cover crop on the soil.

The use of winter crops should find application especially in the Southern States. The winter precipitation, which constitutes a large part of the total, is largely in the form of rain, and in many cases it falls on land barren of any crop. The use of rye or some winter crop would be of great advantage in holding the soil and preventing the destructive erosion resulting from the winter rains.

The method of using hillsides for orchards and maintaining a grass cover crop has given rise to considerable discussion as to the relative value of the orchard with such a crop or with clean culture. As a means of preventing wash, the grass is effective, but the general

¹ Cir. No. 94, Bureau of Plant Industry, U. S. Dept. Agr.

question of the better orchard practice is still a mooted one. Such use for hilly lands is described by Smith ¹ and by Seymour.²

CHECKING EROSION.

In places where erosion has begun, but has not advanced beyond the formation of small washes, it may be checked by filling these incipient gullies with brush, straw, or leaves. Contour plowing across such places is necessary under clean culture to prevent washing. Any field which is steep enough for the development of gullies should be terraced.

A method which has been used, so far as known, in only one locality is the construction of "christophers." (See fig. 1.) This consists of building across the mouth of the incipient gully a dam of earth or stone to hold back the surface run off and keep it on the field. The distinctive thing is the way in which the storm waters are disposed of. Passing through the dam is a sewer pipe connected with an upright pipe on the upper side of the dam. The water fills the valley until it reaches the height of the upright pipe, when it flows through this into the next field. The water left stand-

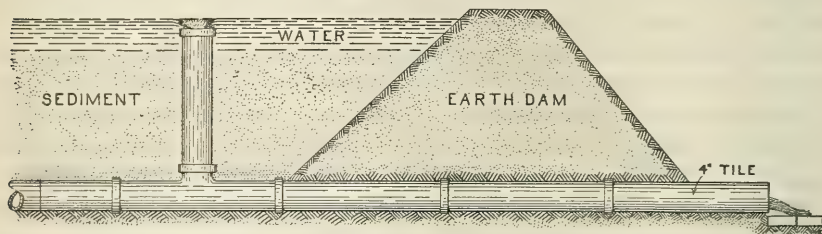


FIG. 1.—A "christopher" with tile drain connection.

ing below the mouth of the upright pipe is removed gradually by a tile drain laid along the valley and connected to the sewer pipe. Rushing water is checked in the valley and deposits its burden of sediment; the water is removed largely by seepage into the tile drain and the ground remains in good condition for tillage.

This method is too expensive for ordinary use, but in cases where it is necessary to use tile drains and the soil washes badly, this is an excellent means of preventing the wash. This method was developed by Mr. John Adams, of Johnson County, Mo., and has been adopted by a number of farmers in that locality. Figure 1 shows the construction of the "christopher."

RECLAMATION OF ERODED LAND.

In the reclamation of eroded land it is necessary to make use of all the methods employed in prevention and to make every effort to stop the advance of the gullies into new lands, and even greater

¹ Smith, J. Russell, *Plow and Poverty*, Sat. Evening Post, 182, p. 14 (1909); *Apples without Plowing*, Country Gentleman 79, 778 (1914).

² Seymour, E. L. D., *The Fruitful Land*, Country Life in Amer., July, 1913.

efforts are required to bring the gullied land to a productive state. In fact, there are many places in which the latter object can not be accomplished economically if at all.

The land is generally reclaimed either for agriculture or for forestry, depending upon the character of the soil and the extent of erosion. For the purpose of forestry it is necessary to study the native vegetation and with the advice of a trained forester, to plant the kind of trees best suited to the climatic conditions of the particular locality. The trees must be generally deep rooted, on account of the lowering of the water table of gullied land, and the extremely rapid drainage afforded by the gullies. Shrubs and grasses may be utilized, and vines afford a protection on the nearly perpendicular face of a deep gully, or on steep slopes.

Most frequently land which is too badly eroded for agricultural use must be reforested in order to be reclaimed. The first effort is to stop the erosion. Trees should be planted thickly in the mouth of and as far up the gully as possible. These will afford an impediment to the water, and the soil material will be deposited. Thus there will be a gradual refilling, and the work should be pushed back toward the head of the gully as rapidly as the washing will permit. The relation of forests to rivers has been discussed by Ashe.¹

It is generally best not to attempt the reclamation, for agricultural purposes, of land which is very badly eroded into gullies. With small washes, the growing of pasture grass, filling the wash with brush or litter and covering with soil is beneficial. In some cases the building of small masonry dams is necessary. If the land is put in cultivation it is wise to begin at once the construction of terraces, to incorporate a large amount of organic matter in the soil, to plow deeply, and, at the outset, to plant deep-rooted crops, such as rye. This produces a physical condition suitable for the ready absorption of water. Immediate results can hardly be expected, as it will take several years of good treatment and constant attention to bring the eroded soil into a state of productiveness.

In the rotation of crops practiced on land which is being or has just been reclaimed from erosion, it is well to include as often as possible crops of rye, grass, and clover, which may be used for pasture.

Two noteworthy examples of the reclamation of eroded lands were observed in the erosion districts of the South. In one case a tract comprising 38 acres, near Johnson City, Tenn., was purchased in 1911 for \$53 an acre. At that time the land was badly eroded, and the owner described it as having then a gully 8 or 10 feet deep. The gully was filled with débris and soil, 200 loads of manure were applied, and the soil was plowed to a depth of 10 inches and planted to rye.

¹ Rept. of the U. S. Inland Waterways Com., 60 Cong., 2d session, S. Doc. 325 (1908).

The rye was being turned under at the time the place was visited, and the soil seemed to be in good physical condition. The owner kept an account of the cost of reclamation, and the total expenditure amounted to \$376, or an average of about \$10 an acre. An offer of \$100 an acre had been refused. The deep plowing and the incorporation of large quantities of organic matter left the soil in such condition that practically all the water falling on the surface was absorbed.

Another example of similar character was encountered near Knoxville. A steep hillside of several acres, which had been badly eroded, was under cultivation by a truck grower. It had been reclaimed by starting terraces and cutting hillside ditches, and when this place was seen it supported an excellent crop of strawberries. The owner had not kept an account of expenses, but had bought the land at a very low price. His greatest trouble was in preventing further erosion. Reclamation at best is an expensive, though not a hopeless, process. It is infinitely better to use preventive measures in the first place.

NATURAL RECLAMATION.

Nature attempts to check excessive soil waste by supplying a natural growth of vegetation to lands abandoned to soil erosion. Trees grow voluntarily in the ditches, and grasses and briars spread over the sides of gullies, retarding the extension of the gullies by erosion. The roots penetrating the soil give it more coherence and increase its resistance to water action. The leaves and other parts of the plants add to the organic matter in the soil, making it more absorptive of the precipitation. This vegetation constitutes an impediment to the water flowing over the surface. The velocity is checked and a part of the burden of soil material is deposited. In this way there is a slow building up of ditch bottoms and a tendency to flatten out the land surface. The natural reclamation begins at the mouth of the gully and extends back to the steep areas. It is not uncommon to find immense gullies with this process taking place, often with large trees growing in them. This is illustrated in Plate I, figure 1.

Nature, however, does not wait for large gullies to form before making an effort to check the erosion. A field abandoned before such devastation has resulted is soon covered with a growth of native brush and trees, which begin at once to prevent the rapid wash of the soil and to reclaim those gullies already begun. In Plate II, figures 1 and 2, abandoned areas, in which a natural growth of pines, shrubs, and grasses has started, are shown.

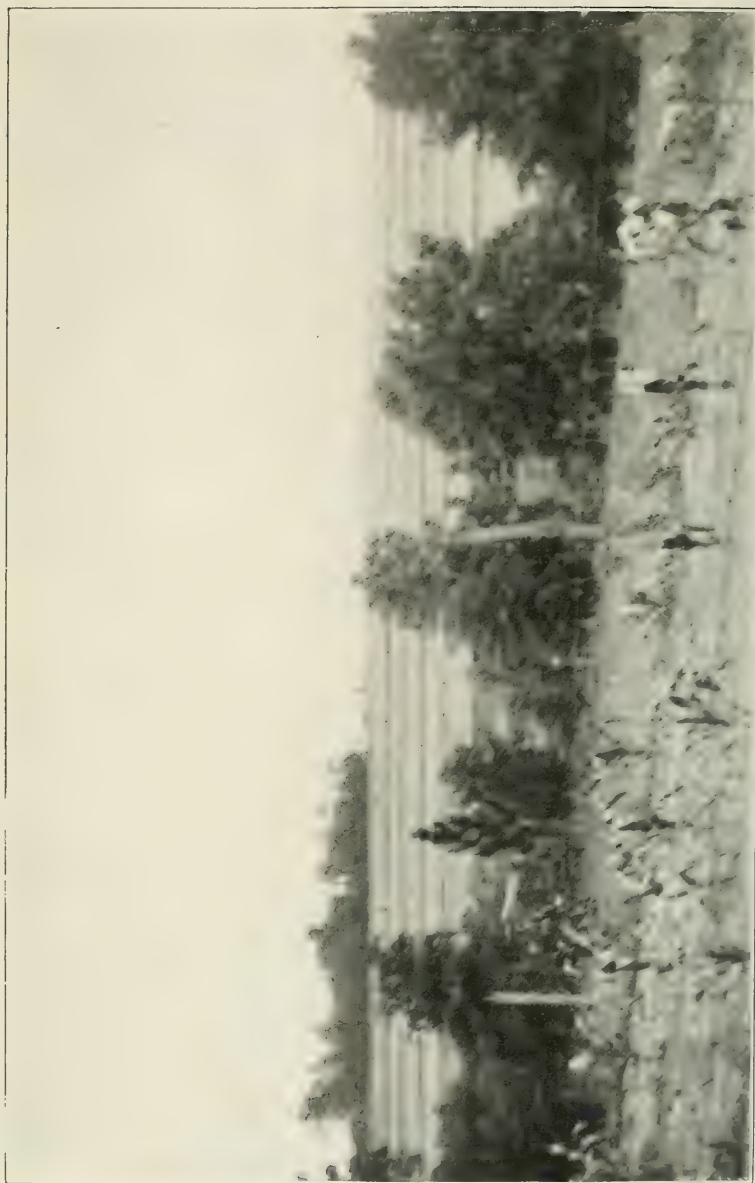
This natural growth often furnishes a suggestion as to the best method of reclamation by reforestation. From the character of the natural growth the kind of trees and shrubs best suited to the soil may be determined, and soils offering no hope of reclamation for agriculture may be used for forestry. One section of the State of Ten-



FIG. 1.—GRADUAL PRODUCTION OF A VALLEY FROM SMALL EROSION GULLY.



FIG. 2.—CAVING GULLY IN SOIL OF SANDY CHARACTER.



A TERRACED FIELD.

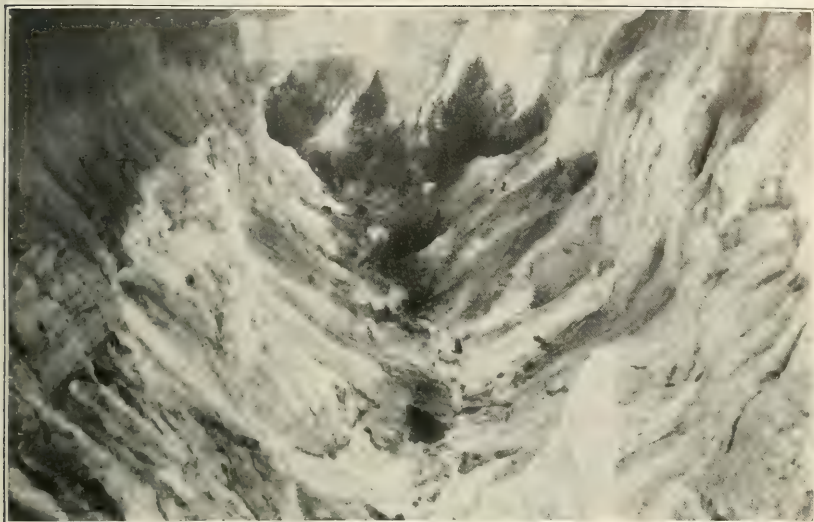


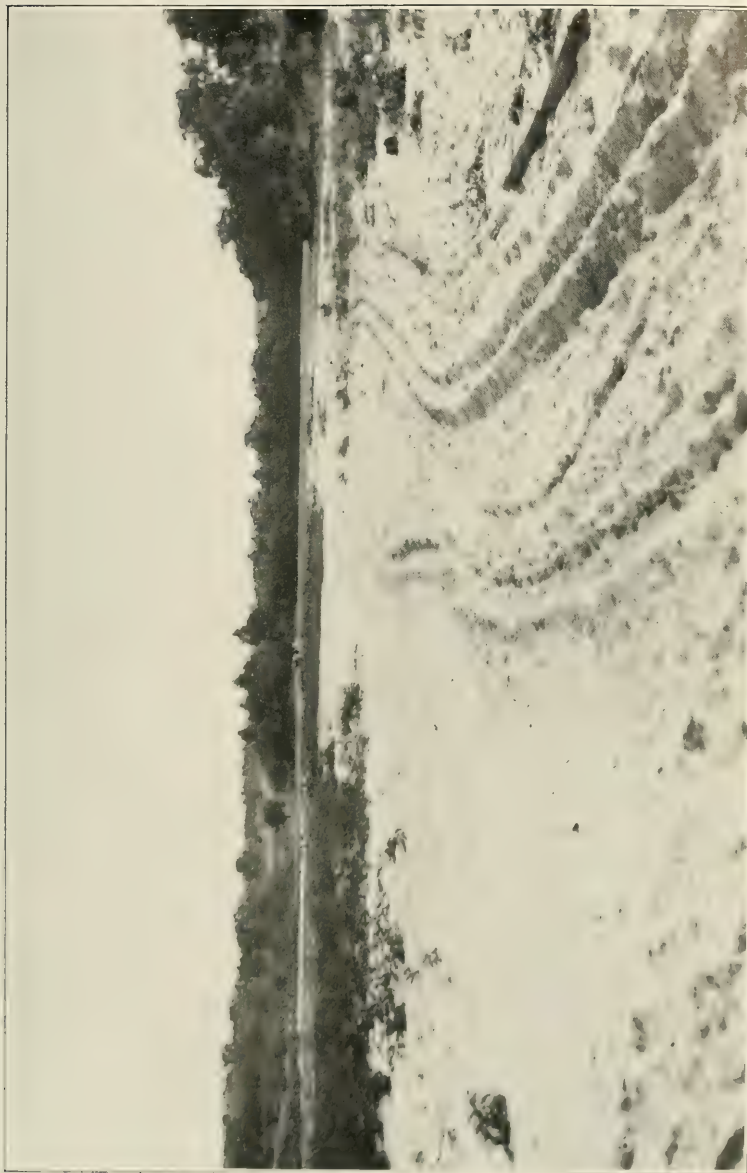
FIG. 1.—GULCH PRODUCED BY CAVING GULLY.



FIG. 2.—HEAD OF GULCH PRODUCED BY CAVING GULLY.



DEVASTATION WROUGHT THROUGH EROSION.



FIELD COVERED WITH SAND FROM ERODING HILLS.

nessee presents such a problem, and the State is endeavoring to solve it by a study of the soil possibilities. The State geologist, working with a trained forester and soil expert, is preparing to reforest a large extent of country that has been injured through erosion.

The natural reclamation of flood plains covered with sand follows the prevention of wash from the hillsides. With the velocity of the water from the hills checked, only the finer material will be carried in suspension to the flood plain. By the continual deposition of silty material over the sand during times of flood, a soil which is well adapted to agriculture will gradually be built up. However, of all lands injured by erosion, it is probably hardest to develop a productive soil over those areas that have been covered to some depth with sand.

ERODED SECTIONS IN THE SOUTH.

Throughout the South erosion is probably worse than in other sections of the country. In the Atlantic Coast States the worst type is encountered in the Piedmont section. It is less marked in the mountains, probably because agriculture is less extensively practiced. Erosion is very marked in some of the States of the Mississippi Valley, some of the worst eroded sections of the country occurring in the hills of these States. It is probable that the climate has much to do with the fact that erosion is so rapid in the South. The character of the soil makes a marked difference in the rates of erosion under the same climatic conditions.

The heavy clay soils erode fairly rapidly, but passing from this heavy clay soil to soils of lighter character, containing a larger percentage of sand, the erosion changes in character from the surface or shoestring type, developing gullies with rounded edges, to gullies with caving sides. These two forms of erosion are illustrated in Plate III, figures 1 and 2. Any marked difference in the character of the soil and subsoil has a great influence on the erosion, which is apparently most rapid in silty soils or in soils having a thin layer of clay at the surface and a substratum of sand or sandy soil, as shown in Plate IV.

The region in the South subject to erosion comprises sections of a number of different soil provinces, the Piedmont Plateau, the Appalachian Mountain and Plateau,¹ the Atlantic and Gulf Coastal Plain, and the Glacial and Loessial regions, the greater part falling within the two first-named provinces. The Piedmont and Appalachian regions differ more in elevation than in character of soil. The Piedmont region extends along the eastern foot of the Appalachian Mountains through Virginia, central North Carolina, western South

¹ Erosion in the Southern Appalachian Region has been discussed by Glenn, with special reference to the effect on stream flow. U. S. Geol. Sur. Paper No. 72.

Carolina, northern Georgia, and central Alabama. It is in this Piedmont Plateau that the greatest difficulty is experienced in dealing with soil erosion.

GEOLOGY OF APPALACHIAN AND PIEDMONT REGIONS.

The soils are mainly residual, i. e., derived from the underlying consolidated rocks. The rocks are of three classes: Old igneous, as diorite, diabase, and granite; old metamorphic igneous and sedimentary, or gneiss, schist, phyllite, and slate; or young sedimentary, as Triassic sandstone, conglomerates, and shales.

SOILS.

Since the soils of these provinces are mainly residual, they are comparatively uniform. The subsoils are nearly always heavy clay, and the surface soils are often lighter in texture. Sandy loams, clay loams, and clays occupy by far the greater part of the province.

Where the subsoil is heavy clay, erosion is not so rapid as in the soils with lighter subsoils. This is noticeable in portions of western Virginia, western North Carolina, and eastern Tennessee, in the Appalachian Mountain province. The erosion begins in little depressions which gradually deepen, forming gullies with sloping banks and rounded edges, as shown in Plate V, figure 1. This is entirely a surface erosion and easily controlled if properly handled. In the mountainous regions terracing is not generally practiced, although without a doubt such a system would prove beneficial.

The Piedmont province of these States and of South Carolina, Georgia, and Alabama suffers more from erosion than the regions of higher altitudes. Especially is this true near the "Fall Line." And in this province also the subsoil is often sandy and less tenacious, so that when a gully forms the sides cave in. The erosion then often proceeds by the caving in of the walls at the head of the gully, so that, in advanced cases, there are formed extensive gulches with almost perpendicular sides. This form of erosion is illustrated in Plate V, figure 2.

The most important soils throughout the Piedmont country belong to the Cecil series, the Louisa soils probably ranking next in importance. These soils are mainly red and gray and have clay subsoils. The main differences in the series are that the Louisa soils are less productive and have more micaceous subsoils than the Cecil. This micaceous character increases their susceptibility to erosion.

The erosion in the Piedmont province is apparently more pronounced in the more southerly States. This is probably due largely to the climatic conditions. During the winter the temperature is not low enough to cause deep freezing, and cold periods are of short duration. The formation of ice crystals at the surface of the soil raises a thin layer, and when the ice melts there remains an inch or

more of very loose, incoherent soil. These freezes and thaws are often followed by heavy rains which sweep away this loose surface layer. This process occurs repeatedly during the winter, and as a result large quantities of surface soil are removed. This soil is not protected from the action of winter rains like the soils of more northerly climates, where the soil is frozen during practically the entire winter, so that the rain can not remove the soil mantle. In addition, the precipitation in more northerly regions is largely in the form of snow, which melts gradually in the spring and is absorbed by the soil, instead of running off over the surface.

Terracing is practiced in the southern Piedmont region, and the destruction of the soil is thus greatly reduced. Since the precipitation is mainly in the form of rain, the soil must be made to absorb as much as possible. This can be done only by employing terraces and the other methods already described. Plate VI shows a well-terraced field in Piedmont Georgia.

One of the peculiar soil conditions encountered in many sections and most conducive to destructive erosion is a surface layer of heavy soil material, varying from 6 inches to several feet in thickness, underlain by sandy material. Erosion on this type of soil produces enormous gulches, 10 to 50 feet deep and several hundred feet wide, sometimes extending for 1 or 2 miles. They begin in the hills adjoining the lowlands, and by constant undercutting and caving push well back into the hills. They are very difficult to stop and often work their way across roadways, farms, forests, and even building sites. It is problematical whether the progress of these gulches can be entirely checked in any profitable way. However, it may be greatly retarded by continually dumping débris, brush, or other material into the gully, by planting wild honeysuckle around the head and sides and young pines or other trees in the mouth. Much soil material will thus be retained and in time the eroded area may be reclaimed. This type of gully is shown in Plate VII, figures 1 and 2. Sandy phases of the Orangeburg and Cecil soils suffer from this type of erosion most frequently.

Similar erosion is encountered in western Tennessee and northern Mississippi, but in a different type of soil. Here the most destructive erosion occurs in areas of silty soils. While the destruction is as great and the devastation possibly more complete, the hope of reclamation is not so remote. For one thing, the depth of the gullies does not generally exceed 15 feet, because more resistant material is encountered at about this depth. The sides are slightly less abrupt and there is a better opportunity for the growth of wild plants or even the gradual reclamation by reforestation.

Some of the lands have been stripped of their natural growth of timber by rapid erosion. Frequently a surface layer of heavy soil, less than a foot thick, covers a subsoil of much lighter material, in

some places sandy, extending to a considerable depth. Where such areas are forested erosion is slow, but with the removal of the forest growth the erosion is very rapid. Any rut or path breaking through the upper layer of heavy soil soon develops into devastating erosion. In some places, owing to this condition, any attempt to cultivate the soil should never be made. With plowing and clean cultivation it is practically impossible to prevent erosion. In a few counties a rough estimate places the eroded and abandoned areas at 25 to 33 per cent of the total.

The great danger of losing large areas of valuable land is appreciated in Tennessee, and under the direction of the State geologist the best methods of preventing erosion and reclaiming eroded land are being studied. Plate VIII illustrates the seriousness of the situation in some parts of the State. The main problem is to arouse the farmers to a realization of the importance of treating their soil in the manner best suited to its condition. Soils that can not be cultivated without danger of erosion should be used for the production of hay, for pasture, or for forestry, either of which may pay better under the circumstances than the crops obtained from clean cultivation.

In extreme western Tennessee and Mississippi the deep silty soils erode in a slightly different way. The soils of nearly uniform composition to a great depth are compact and the pore spaces are comparatively large, so that in their natural condition they absorb much of the water falling on the surface. The surface soils and subsoils having the same composition, the sides of cuts are vertical, with very little tendency toward caving, such as occurs where the subsoil becomes saturated and is washed out, leaving the surface layer without support. The attrition of the surface, producing a loose layer, furnishes the most favorable condition for the ready removal of the soil by water, the loose soil being readily carried away with the surface run-off. This condition is most noticeable in old roadways which have been lowered by erosion sometimes 15 to 20 feet, and the vertical walls along the sides show little effect from later rains. The control of this type of erosion by terracing is a simple matter. Any sort of growth completely covering the ground will prevent the excessive removal of soil material.

DAMAGE TO FLOOD PLAINS.

In clearing slopes hillside erosion is often so increased that the streams carry a much larger burden of material than usual. The excess material is deposited in the lower courses of the streams, causing a filling or shifting of the channel. One result is that in times of heavy run-off the stream channel is not sufficient to carry the increased volume of water and overflows result. The flood plain

is either covered with a layer of sand or is scoured into ditches and smaller channels, impairing the agricultural value of the land.

In some of the districts of the South the gullies, which are ordinarily dry, become filled with rapidly flowing water. This temporary stream carries a heavy burden of soil material, much of which is sand, as the soil conducive to the formation of these gullies is generally sandy. The velocity of the water is first checked in the valley and the sand is largely deposited. A formerly productive field covered in this way with a layer of sand 6 inches to 2 feet in thickness is shown in Plate IX.

AGRICULTURAL PROBLEMS.

As previously pointed out, the greatest damage from erosion generally occurs where the original growth has been removed and the land in being used for crop production. This most frequently means clean culture. The agricultural conditions in the South are especially favorable for erosion, as the main crop is cotton, which requires entire freedom from grasses and weeds. The rotations practiced may include some other clean cultivated crop, as corn, but in a great many cases cotton is the only crop grown.

The labor problem and other economic conditions have much to do with this system of farming. Ordinarily the small farmer and the tenant can obtain credit only by growing crops that can not be easily disposed of without the creditor's knowledge. The crop that meets all conditions best is cotton. Hence it oftens happens that the same land is cropped year after year to cotton, until the soil becomes so unproductive that its cultivation is not profitable, when it is allowed to "lie out," and becomes infested with weeds. It is then that erosion is most destructive. The soil is exhausted of organic matter, and even before the weeds begin to grow the rains form gullies over the surface. Probably the field will not be put under cultivation again, and in a few years it becomes devastated, without agricultural value, and a menace to the surrounding land.

The question of erosion must be considered in adopting crop rotations. In addition to the use of terrace and hillside ditches for checking the soil wash, it must be remembered that the incorporation of large quantities of organic matter produces an open, porous soil, capable of absorbing water, and that deep plowing furnishes a sub-soil reservoir for the storage of surplus water. It is not always possible to practice these methods with certain crops, so that the tendency to erosion and the effects of certain practices must be considered before a given crop is included in the rotation. The Georgia experiment station,¹ for example, has conducted experiments which indicate that plowing below 8 inches lessens the yield of cotton. It is also known that the quality of tobacco is injured by legume

¹ Ga. Agr. Expt. Sta., Bul. 63, p. 124.

humus, although rye has no bad effect. If corn or other exhaustive crop precedes tobacco, the legume humus does not injure the tobacco. The presence of large quantities of humus in a soil tends to produce weedy cotton and to retard its maturity. It is thus apparent that the rotation worked out and the means employed in reducing erosion must be adapted to the crops desired and the soils on which they are to be grown.

The loss in productiveness alone should make it worth while to prevent erosion, not to mention the rapid depreciation of the money value of eroding lands. The amount of material removed from hilly land by erosion is enormous. The amount of solid material carried to the sea by the Potomac River is estimated ¹ at 400 pounds per annum to every acre drained by it. The James River, with a flood of 10-foot crest, is said to remove an average of 275,000 to 300,000 cubic yards of solid material within each 24 hours, and to remove annually 3,000,000 or 4,000,000 cubic yards from the region above Richmond, in Virginia.² The loss from erosion on moderate slopes in the Piedmont region of North Carolina is said to amount to about \$3 an acre yearly in decrease in crop value alone, making the total annual loss in this region over \$2,000,000.³ Since there are many hilly farms on which excessive erosion is effectually prevented, the eroded areas must far exceed this estimate in actual loss.

ECONOMIC LOSSES.

The losses resulting in depreciation of the land from erosion are only part of the total losses occurring from this cause. Large amounts are annually expended in removing from stream channels and storage reservoirs sediment brought down by rivers. In many places the sediment collects so rapidly that it has been found practically impossible to maintain the reservoirs, and the method of simply keeping a channel open has been adopted. This, of course, entails great losses in water power and in navigation. Many river bottoms fill so rapidly that it requires continual dredging to maintain channels for purposes of navigation. In the rivers of the Southern States the sediment carried is one of the great difficulties in developing power sites. Because of the peculiar soil conditions and the fact that practically all of the precipitation in both the valleys and the headwaters of the streams is in the form of rain, the rivers carry a great burden of sediment. In testimony before the Agricultural Committee of the House of Representatives in 1908, W. S. Lee stated that the capacity of the reservoirs of the Southern Power Co. on the Catawba and Broad Rivers in South Carolina was so reduced that in a few years only the flow of the rivers would be available.

¹ U. S. Geol. Sur. Bul. 192.

² Rept. Chief of Engineers, U. S. Army, 1885, pt. 2, p. 847.

³ Bul. 17, N. C. Geol. Sur.

In navigable streams the deposition of this sediment in the stream bed causes a filling or shifting of the channel and the formation of bars. The Roanoke River is reported to carry 3,000,000 tons annually, the Alabama 3,039,900 tons, the Savannah 1,000,000 tons, and the Tennessee 11,000,000 tons, while other rivers carry like amounts.¹ This indicates the extent of the loss of soil material, together with the additional losses just described.

The economic aspect of soil erosion has been discussed by a number of authorities,² who agree that the United States is losing millions of dollars each year from this cause. The report of the National Conservation Congress, 1909,³ states that in the United States there are 6,076 square miles of farm land, or 3,888,640 acres, devastated by soil erosion an area which is equal to 100,000 farms of nearly 40 acres.

SUMMARY.

Soil erosion is a natural process, tending to level the land. Generally under natural conditions it is slower than the formation of soil material from the parent rocks.

Destruction of the natural growth and clean cultivation on hilly land, without protection against erosion, results in the removal of the soil material by water more rapidly than it is formed and in a very irregular manner.

Owing to the climatic and soil conditions the South is especially susceptible to excessive erosion. The economic conditions and type of agriculture of this section also contribute to the excessive erosion.

Methods of prevention should be practiced wherever hilly land is used for crops. Terracing is the best and most efficacious method, but should be supplemented by deep plowing and the incorporation of organic matter when permissible.

The agricultural problem involves the adoption of proper crop rotation in connection with preventative methods best suited to soil conditions and crop production.

The reclamation of eroded land is possible, but requires careful attention and patience. The use of such land for forestry is commonly advisable. Nature effects reclamation, but the process is slow and tedious.

The losses annually to agriculture and in expenses incurred at power sites and in maintaining navigable channels are enormous, and constitute one of our greatest national wastes.

¹ Amer. Rev. of Rev., 89, 439 (1909).

² See: N. S. Shaler, Economic Aspect of Soil Erosion, Nat. Geog. Mag., 7, 328-38 (1896); T. C. Chamberlain, Soil Wastage, Proc. of Conf. of Governors on Conservation, House Doc. 128, pp. 75-83 (1908); Pop. Sci. Mo., 73, 5-72 (1908); W. W. Ashe, Waste from Soil Erosion in the South, Amer. Rev. of Rev., 39, 439-43 (1909).

³ Report Nat. Con. Cong., S. Doc., No. 676, 60th Cong., 2d sess. (1909).

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 181

Contribution from Office of Experiment Stations
A. C. TRUE, Director

Washington, D. C.

PROFESSIONAL PAPER

April 12, 1915

A REPORT ON THE
METHODS AND COST OF RECLAIMING
THE OVERFLOWED LANDS ALONG THE
BIG BLACK RIVER, MISSISSIPPI

By

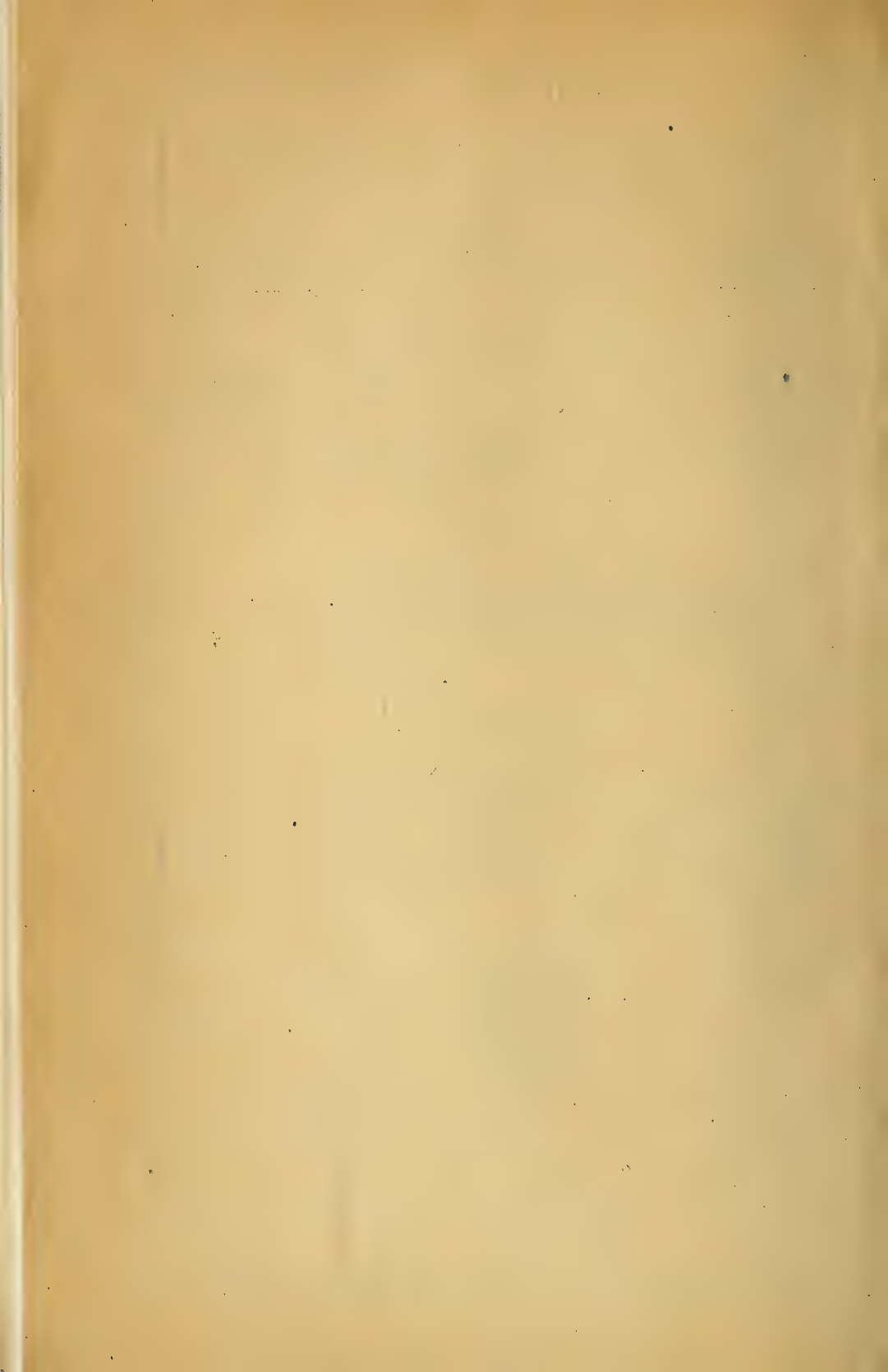
LEWIS A. JONES, Drainage Engineer
Assisted by W. J. SCHLICK, Drainage Engineer, and
C. E. RAMSER, Assistant Drainage Engineer

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A REPORT ON THE METHODS AND COST OF RECLAIMING THE OVERFLOWED LANDS ALONG THE BIG BLACK RIVER, MISSISSIPPI.

By LEWIS A. JONES, *Drainage Engineer*, assisted by W. J. SCHLICK, *Drainage Engineer*,
and C. E. RAMSER, *Assistant Drainage Engineer*.

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INTRODUCTION.

With the cutting of the most valuable timber from the swamp and overflowed areas of the South, it becomes evident that future returns from these lands must be sought in agriculture. The first step toward rendering such areas available for cultivation is drainage. The conditions along the Big Black River in Mississippi are fairly representative of conditions that exist in greater or less degree on many southern streams.

In November, 1912, the attention of Drainage Investigations, Office of Experiment Stations, United States Department of Agriculture, was called to the conditions along the Big Black River and assistance in devising a plan of reclamation was requested. A preliminary examination of the district was made February 14 to 22, 1913. An agreement was entered into under which Drainage Investigations undertook to make a survey of the area and to prepare plans for its reclamation, the district agreeing to contribute to the expense of

NOTE.—This report is intended for engineers, landowners, and others interested in drainage enterprises in regions where the conditions are similar to those here described; it is suitable for distribution in the Gulf Coast States.

the work. Field work was begun April 20 and finished August 15, 1913.

The following report describes briefly the conditions found, discusses the drainage problems encountered, and presents the plan of drainage considered most practicable. It is believed that this information will be decidedly helpful to engineers, drainage district officials, residents, and owners of property in many localities where overflowed lands are to be reclaimed.

GENERAL DESCRIPTION OF THE DISTRICT.

LOCATION AND AREA.

The lands examined comprise that section of the valley of the Big Black River beginning near its source in Webster County, in the central part of the State of Mississippi, and extending in a south-westerly direction to the Alabama & Vicksburg Railway bridge, 14 miles east of Vicksburg, a total distance in a direct line of about 150 miles (see fig. 1). The bridge referred to is about 30 miles above the junction of the Big Black River with the Mississippi, and marks the head of navigation on the former stream. The total area of the flooded land above Cox Ferry, the lower end of the proposed improvements, is 133,460 acres.

TOPOGRAPHY.

THE WATERSHED.

The watershed of the Big Black River consists of bottom land from one-half mile to $2\frac{1}{2}$ miles wide, bordered by rough, rolling land and steep hills which extend back a few miles from the bottoms. The surface of the rest of the watershed is rolling and in places quite rough. In general the topography of the land is such that the run-off is large and reaches the main streams in a short time. It is estimated that 75 per cent of the upland has been cleared and was at one time in cultivation, but a large part of it is now eroded and has been allowed to grow up to pine and brush thickets. The areas draining into the river at various points are shown in figure 2.

The bottom lands are comparatively level, being broken only by sloughs, old "ox bows," and bayous, formerly portions of the river channel. In general the banks of the river are from 1 to 3 feet higher than the land at the foot of the hills. From Mathiston to Goodman the bottoms average from 1 to $1\frac{1}{2}$ miles wide, and from Goodman to Cox Ferry, near the Yazoo County line, the average width is from 2 to $2\frac{1}{2}$ miles. At Cox Ferry the bottoms begin to narrow rapidly, and from a point 2 miles below the Ferry to the Alabama & Vicksburg Railway bridge average but from one-fourth to one-half mile in width. The valley has a fall of 3 feet per mile at

the upper end of the district; this gradually decreases to $1\frac{1}{2}$ feet per mile at the lower end.

Not more than 15 per cent of the bottom land is cleared; the remainder is either in virgin timber or is cut-over land covered with a dense growth of cane, brush, and briars. The cleared land lies along the edge of the bottoms or in small tracts or ridges that are from 1 to 3 feet above the general elevation of the adjoining bottoms.

STREAMS.

In the upper part of the area covered by the survey the Big Black River has a channel varying from 30 to 75 feet in top width, from 20 to 50 feet in bottom width, and from 5 to 15 feet in depth below the general elevation of the ground; in the lower part the channel varies from 150 to 250 feet in top width, 75 to 100 feet in bottom width, and is from 15 to 25 feet deep. Throughout its entire length the channel is very crooked and is filled with drift and brush.

The length of the river channel through the portion of the valley covered by this report is 1.7 times that of a line drawn down the general course of the valley. The banks are well defined and are covered with a dense growth of cane and briars. The bottom of the river is a silty loam or clay. At one point near Hoffman and at one or two points in the vicinity of Edwards there are traces of rock, but the formations are local and occur where they will not affect the proposed work.

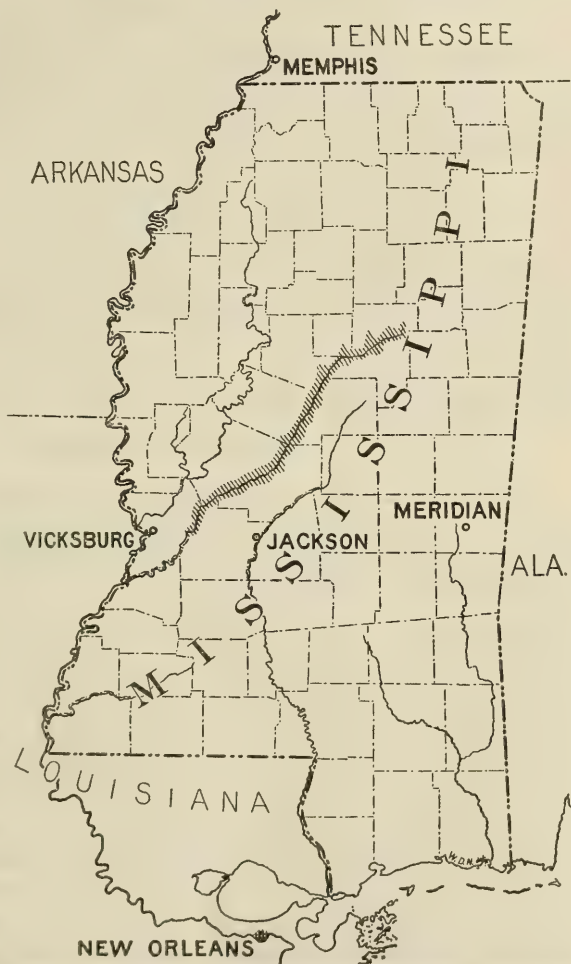


FIG. 1.—Map of Mississippi, showing location of Big Black River project.

Numerous creeks and ravines drain into the river; these vary in size from streams with watersheds of 150 square miles to those draining but one or two square miles. Figure 2 (in pocket at end of bulletin) shows the location and extent of each of these tributaries. Their channels, though smaller, are similar to that of the river.

CLIMATE.

The climate is typical of that of the Gulf States. Frequently during the summer the temperature reaches 95° F. and maintains that height for a considerable length of time. The winters are usually mild, and it is very seldom that the temperature falls to zero. The records of the United States Weather Bureau at the Yazoo City station show a maximum temperature of 107° and a minimum of -2°, with a mean annual temperature of 65°.

The mean annual precipitation during the past 12 years was 48.1 inches. The rainfall is well distributed throughout the year, the least occurring during the cotton-picking season of September, October, and November. A more extensive discussion of rainfall will be found in the section of this report dealing with run-off (p. 7).

AGRICULTURAL CONDITIONS.

Throughout the Big Black bottoms the soil is very uniform in character, being composed of a silty loam underlain by clay. The type is called "meadow" by the United States Bureau of Soils and is described by the bureau as follows:¹

The surface few inches of the material composing the meadow consists of a brown or drab silt loam. This is underlain by a drab, gray, or bluish silt or silty clay. In local areas and especially near streams there is considerable sand present in both soil and subsoil. * * * The type is still in process of formation, each successive flood bringing with it material that is left as a thin deposit over the bottoms. The soil is very rich, and if cleared, ditched, and diked would be capable of producing large yields. At present it is of value only for its timber and the pasture it affords.

The soil of the uplands is largely a brown or light brown loam, underlain by a brown clay. It is considered fertile, but is very easily eroded.

The bottoms, which are at present unsuitable for tillage, were originally covered with a heavy growth of timber consisting of water oak, black and sweet gum, sycamore, beech, and some cypress. The greater part of the valuable timber has been cut, and a second growth, together with a heavy stand of cane, brush, and briars, now covers the bottoms. With regard to lands bordering streams in Mississippi, it is generally recognized that heavy growths of timber indicate lasting productiveness of the soil, and that rank growths of underbrush, cane, and vines, such as occur in these bottoms, are seldom found on poor land.

¹ U. S. Dept. of Agr., Bureau of Soils, Soil Survey of Holmes County, Miss., 1909.

As in most of the Southern States, cotton is the principal agricultural product, its acreage exceeding that of all other crops combined. Next to cotton, corn is the most important crop, although the production scarcely meets the local demand. Oats, cowpeas, and sugar cane are all grown to a limited extent, but are gradually increasing in acreage. In the vicinity of Durant the trucking industry has been developed to some extent, considerable quantities of strawberries, cabbage, peas, beans, etc., being profitably grown. The planters are becoming interested in live stock and small quantities of lespedeza and alfalfa are being planted. The injurious effect of the boll weevil on cotton has led more toward diversified cropping during the last five years.

TRANSPORTATION FACILITIES.

Several railway lines traverse various portions of the district. At each of the larger towns bordering the district and at one or two other points public highways are maintained across the bottoms. In all cases where any attempt is made to promote traffic during the winter months the cost of maintenance is very great, and even then many of the roads are impassable during the winter and spring seasons. Drainage improvements will, to a large extent, remedy these conditions.

PRESENT DRAINAGE CONDITIONS.

Under present conditions a heavy rainstorm, lasting from two to three days and extending over the entire watershed of the Big Black River, will cause a severe flood, covering from 75 to 100 per cent of the bottom lands to a depth of from 3 to 8 feet. Unusually heavy local rains, although extending over only a small part of the watershed, will often cause floods over the adjoining bottoms below the area affected by the storm. Floods occur most frequently during the winter and spring seasons, the water often covering the lowlands for a month at a time. From May to November overflows are less frequent, although several ruinous summer and fall floods have occurred. Thus there is great risk in planting crops on the lower land, and it is not entirely safe to plant on the more elevated portions of the bottom. So often have losses been sustained that it is now difficult to find anyone who will finance the working of the land.

Throughout the district the bottom lands of the streams tributary to the river are overflowed at all seasons of the year to a depth of from 1 to 3 feet. In the smaller creeks, from 1 mile to 8 or 10 miles in length, the overflow usually starts a short time after a heavy rain begins, and continues from four to five hours after the rain ceases. On account of their more extensive watersheds the lowlands along the larger tributaries, such as Bywy, Apookta, and Doaks Creeks, are flooded from one to two days after each severe storm that lasts a day or more.

Below the Alabama & Vicksburg Railway bridge the river has been declared navigable and the landowners are urging the United States War Department to improve the condition of the channel. There are a great many drifts in this section of the river, and the carrying capacity of the stream undoubtedly would be increased if its conditions were improved.

No extensive attempts at drainage have been made in the district investigated. One or two property owners have constructed small ditches to drain their fields after the floods have receded, and others have protected small fields by the construction of levees.

THE SURVEY.

In making the survey, base levels were first run along the railroads bordering the valley. Bench marks were established at intervals of 1 mile or less on railroad mileposts or other convenient objects.

The flood lines or edges of the overflowed land were located by compass and stadia. Lines of levels were run across the bottoms at intervals of approximately 1 mile, and all of the streams and larger sloughs were meandered. Levels were carried on all of these meander lines and bench marks established at intervals of approximately 1 mile. Cross sections of the streams and sloughs were taken at frequent intervals to determine the sizes and capacities of the channels.

Soil borings 15 feet deep were taken at intervals of one-half mile on the cross lines in order to ascertain the character of the soil to be encountered in excavation.

Department bench marks were set near a number of the towns, their locations being shown on the map (fig. 10), and their elevations and locations being given in Appendix I of this report. These bench marks consist of iron pipes, $3\frac{1}{2}$ feet long and 3 inches in diameter, set in the ground to a depth of 3 feet. The top of each pipe is covered with a bronze cap on which is stamped "Office Experiment Stations, U. S. Dept. Agr. Drainage" and the elevation of the top of the bench mark to the nearest foot. All bench marks set were of a permanent nature. Those placed on trees were made by cutting a notch in the root and driving in a spike, the elevation being taken on the head of the spike. A few bench marks were established on bridge piers and tops of culverts. All of these, other than the department bench marks, are inscribed "U. S. B. M.," followed by the initial of the instrument man and a serial number. Their numbers and location are shown on the map and their elevations may be had by application to Drainage Investigations. All elevations refer to Gulf datum as established by the United States Geological Survey.

Very little time was spent in locating land lines, and as the original corners and lines have practically become obliterated it was necessary to tie the survey to known objects, such as railroad mileposts, roads, etc. The land lines shown on the map were obtained by adjusting

the original field data secured by the General Land Office to fit the location of corners as determined by the drainage survey. The main watershed boundary was obtained from data given on the township plats prepared by the General Land Office. All data gathered during the survey were plotted before the field was abandoned, and are shown on the map (fig. 10). None of the proposed improvements was located on the ground.

THE DRAINAGE PROBLEM.

To obtain relief from present flood conditions along the Big Black River an adequate outlet must be provided for the water that flows from the hills on to the bottom lands after each heavy rain. The tortuous river channel, choked with drift and brush, is wholly insufficient as an outlet, and the heavy growth of underbrush and cane makes it impossible for the water to flow over the bottoms with any degree of rapidity. The problem is to open a waterway of sufficient capacity to carry the water off as rapidly as it reaches the bottoms. This must consist either of (1) a system of ditches and channel improvements to carry the water below the ground surface, (2) a system of levees and a floodway to carry the floodwater above the surface of the ground without damage to adjoining land, or (3) a combination of (1) and (2). The remaining pages of this report are devoted to a treatment of the various features entering into the design and construction of an efficient drainage system for these overflowed lands. Hydraulic problems are discussed, the feasibility of a number of drainage plans examined, and detailed cost estimates for the recommended plan given.

RUN-OFF.

Run-off is that part of rainfall which flows over or through the ground to drainage channels. The success of drainage improvements depends upon their ability to care for the run-off, hence it follows that the determination of the rate of run-off is of the utmost importance in the design of such improvements. This rate is ordinarily expressed in the number of cubic feet per second removed from each square mile, or in depth of water, considered as distributed uniformly over the watershed, removed in 24 hours. In this report the rate of run-off is usually expressed in the number of second-feet per square mile of drainage area.

FACTORS AFFECTING RUN-OFF.

Since all run-off is due to precipitation, it is obvious that the latter is the most important element in the study of run-off. Other factors that have more or less effect upon the rate of run-off are the size, shape, and topography of the watershed, character of soil and vegetation, rate of evaporation, and the water storage capacity of the streams, sloughs, and bottoms.

DETERMINATION OF RATE OF RUN-OFF.

By the establishment of a sufficient number of measuring stations over the watershed, the amount of rain falling during any period of time may be determined with comparative accuracy. However, the rate of run-off is influenced not only by the total amount of rain falling, but also by the duration, intensity, frequency, and distribution of storms, it being the composite effect of the rainfall occurring during the overflow together with that of other recent storms. Thus it may be seen that the determination of the maximum rate of run-off becomes a complex problem.

The most reliable method of ascertaining the maximum rate of run-off for any district consists in making accurate measurements of the amount of water flowing from the district during its highest flood. Since in most cases it is impossible to obtain this information for the stream under consideration, recourse must be had to other methods. Fairly reliable data may be obtained by investigating some stream in the same locality with the one in question whose channel and watershed are of similar size, shape, and slope, where the soil and vegetation are similar, where rainfall records are available, and run-off measurements have been made.

No run-off measurements for the Big Black River watershed have been made, but such measurements have been taken on the Pearl River watershed which adjoins that of the Big Black on the east, and which is quite similar in size, shape, topography, character of soil, and vegetation. The rainfall data collected at the Weather Bureau stations near the divide between these rivers are applicable to both watersheds. It was therefore decided to investigate the run-off of the Pearl River and to apply the results obtained to the Big Black watershed. As the size, shape, and topography of the watersheds, character of soil, and vegetation are quite similar, it was assumed that the effect of these factors would be the same on both watersheds.

RUN-OFF FROM PEARL RIVER WATERSHED.

A gauging station was established by the United States Geological Survey on the Pearl River at the county highway bridge near Jackson, Miss., June 24, 1901. From that date until the present time continuous daily gauge readings have been recorded and numerous discharge measurements have been made for river stages ranging from that of minimum flow to within a few feet of the maximum recorded by the gauge. From these data a discharge curve was constructed, and by extending this the corresponding discharges for higher gauge heights were estimated. The maximum discharge obtained in this manner is the probable maximum discharge that will occur under existing drainage conditions. If drainage improvements were made, a greater rate of run-off would result, since the water falling would immediately be

removed from the surface of the ground instead of being allowed to accumulate over the bottoms as storage. In order to ascertain this increased rate of run-off it is necessary to make a careful study of

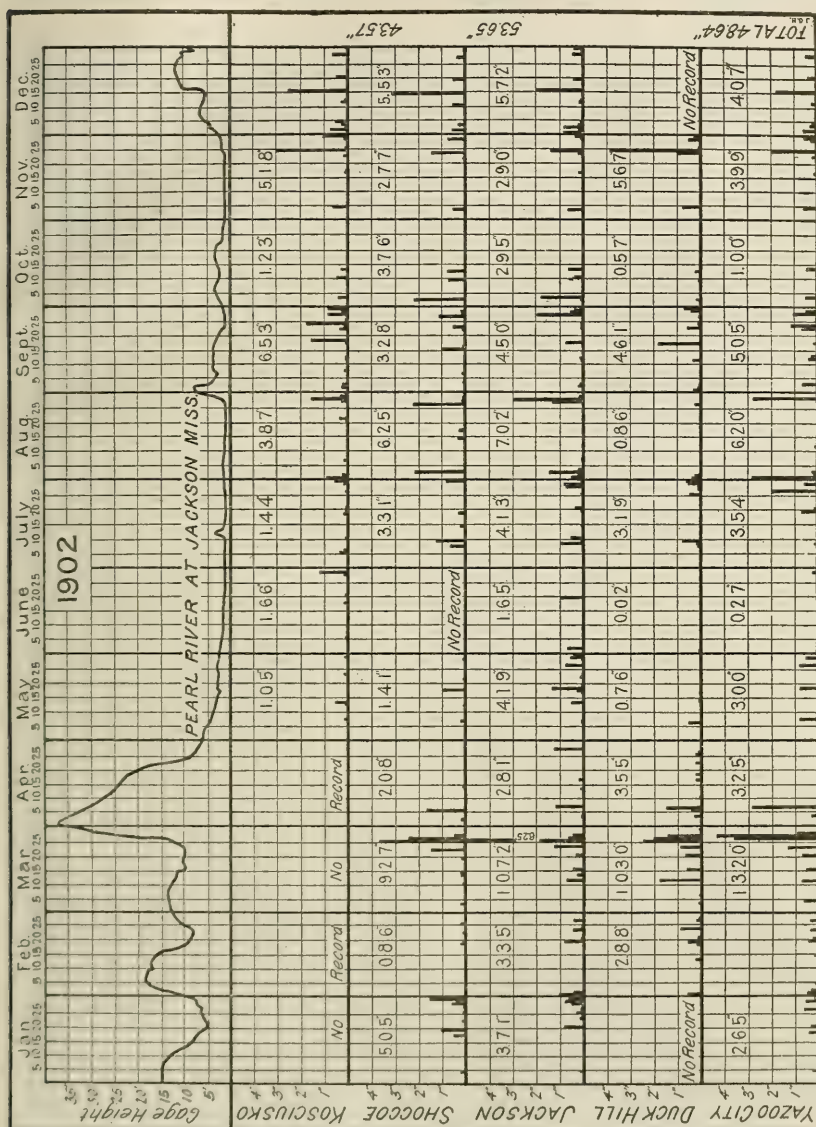


Fig. 3a.—Hydrograph of Pearl River and daily precipitation in vicinity of Big Black River, 1902.

rainfall and run-off conditions on the Pearl River for the maximum storms and flood conditions recorded.

The rainfall records of the United States Weather Bureau for stations on the Pearl River watershed show that the two greatest protracted and general rains occurring since 1898 were in March, 1902,

and May, 1909. The maximum river stage recorded at Jackson since 1901 occurred on April 1, 1902, being 37.2 feet; the next highest reading recorded was 35.3 feet on May 30, 1909. Flood stage as fixed by the Weather Bureau is 20 feet on the gauge.

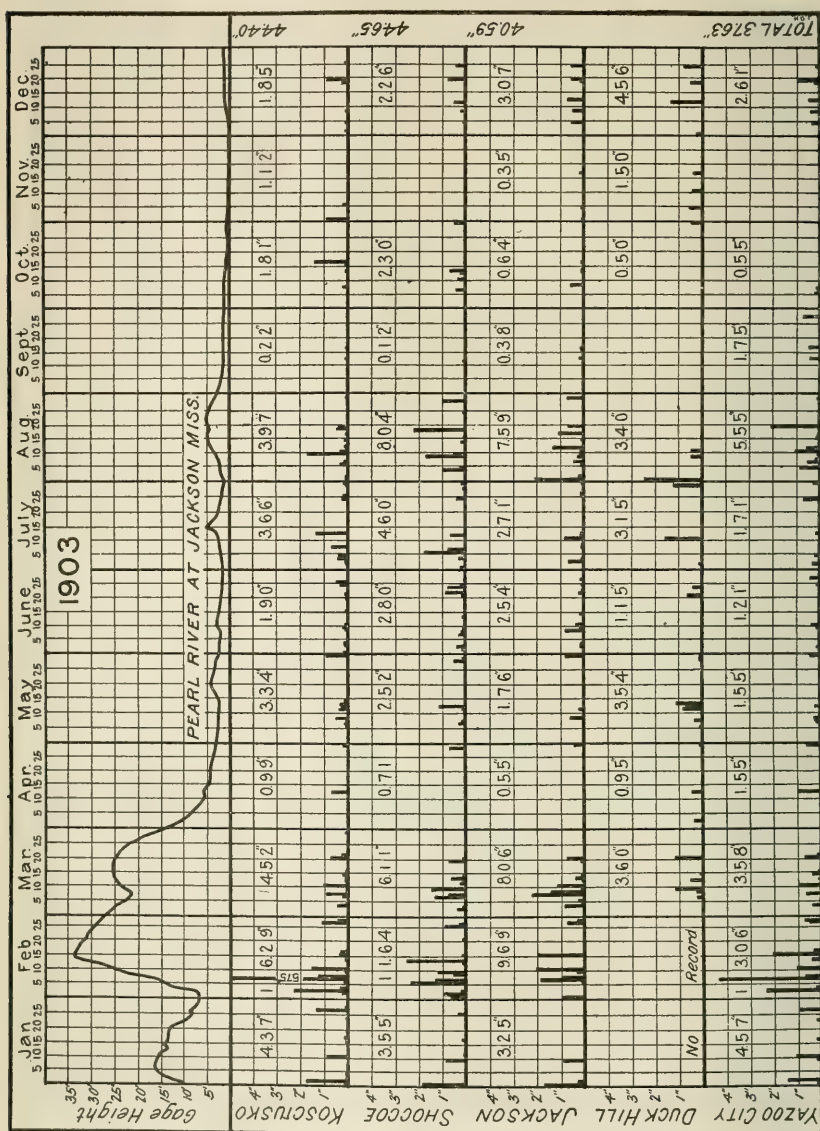


FIG. 3b.—Hydrograph of Pearl River and daily precipitation in vicinity of Big Black River, 1903.

A study of the gauge readings at Jackson (fig. 3a to fig. 3l, inclusive) shows that the river reached flood stage 18 times in the 12 years for which the records are given, and that the floods occur at all seasons of the year, the summer and fall floods reaching practically the same

heights as the winter floods. By studying the rainfall data plotted below the hydrograph, and by referring to the watershed map (fig. 2), a clear idea can be obtained of the intensity and extent of the rainfall causing the floods, features that are of great importance in determin-

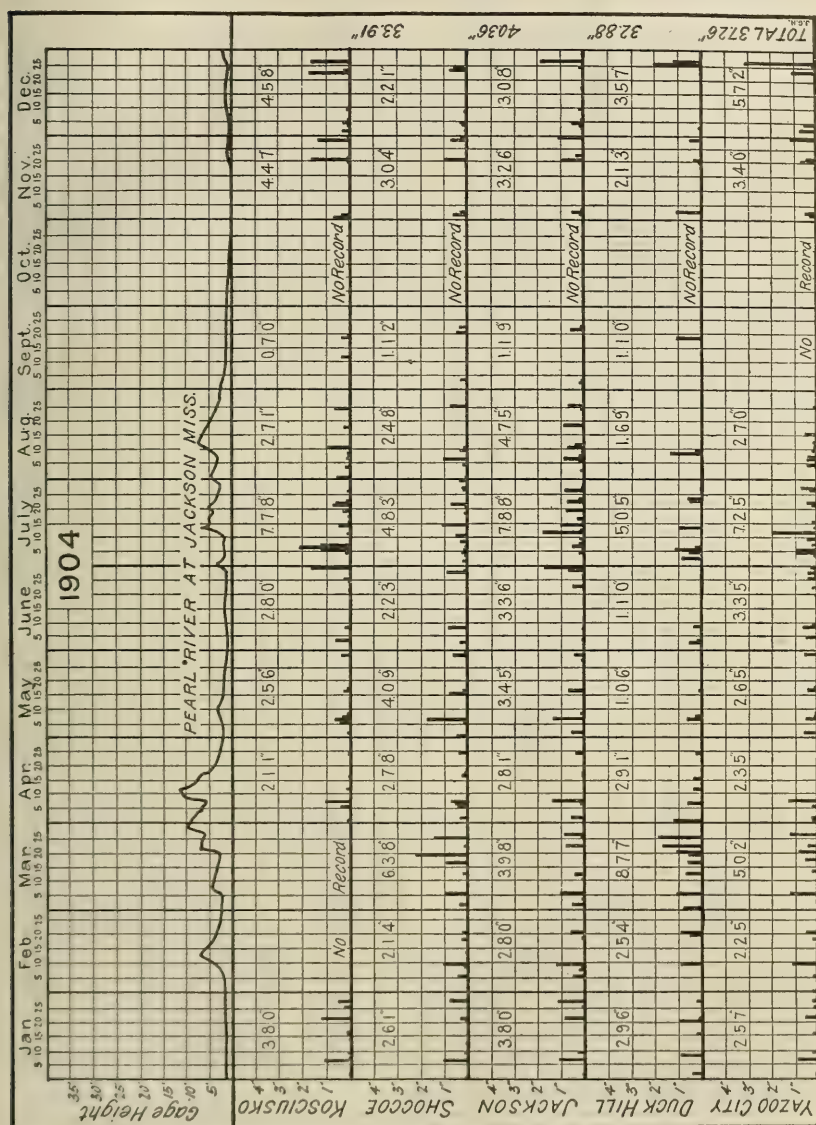


Fig. 3c.—Hydrograph of Pearl River and daily precipitation in vicinity of Big Black River, 1904.

ing the maximum rate of run-off. A method of determining the probable maximum rate of run-off by the use of the hydrograph of the Pearl River at Jackson was suggested by C. E. Ramser, assistant drainage engineer, and is given below.

The hydrograph shown in figure 4, A, is that for the Pearl River at Jackson, Miss., covering a period from May 18 to July 17, 1909; it indicates all fluctuations in rate of run-off during that period. The

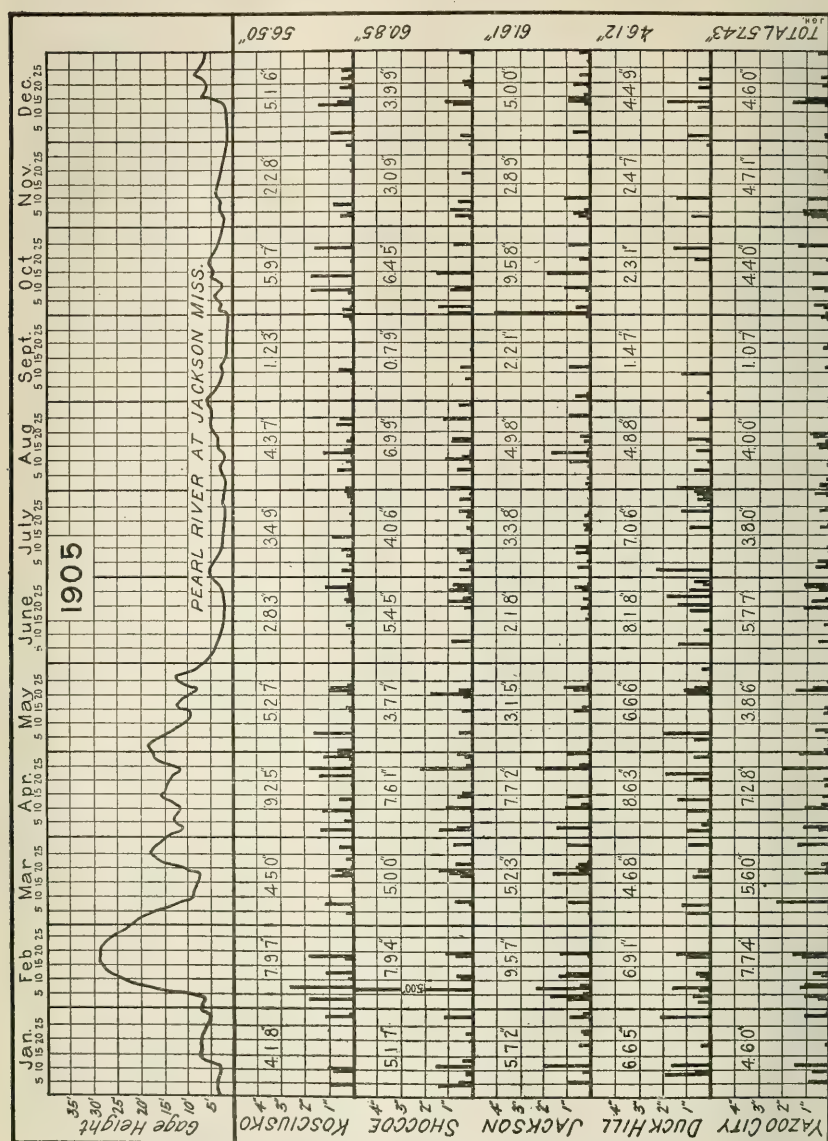


Fig. 3d.—Hydrograph of Pearl River and daily precipitation in vicinity of Big Black River, 1905.

initial rise occurring on May 18 was due to the rain of May 15, and the final rain affecting the run-off for the period considered occurred on July 9. The upper curve of the diagram represents the actual rate of run-off for the period; the lower curve indicates what the rate of

run-off would have been for the same period had there been no rain after May 20. This lower curve was obtained by plating a portion of the continuous hydrograph of the Pearl River for a period of

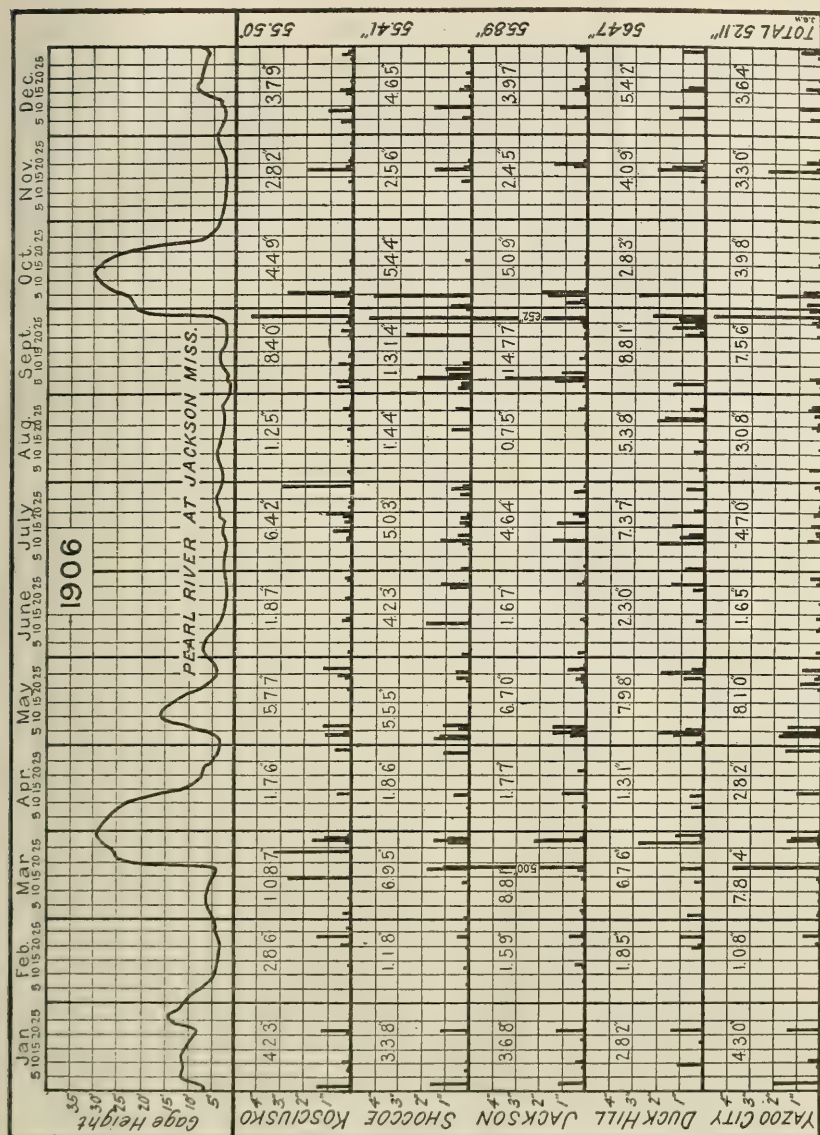


Fig. 3e.—Hydrograph of Pearl River and daily precipitation in vicinity of Big Black River, 1906.

practically no rainfall equal to the period May 24 to July 17, a point of beginning on this hydrograph being taken where the discharge equaled that of May 24. The area between the upper and lower curves represents the total amount of run-off due to the period of

rainfall considered. This area equals 23.35 square units. One square unit being equal to 4 days (reduced to seconds) multiplied by 8,000 cubic feet per second, or 2,764,800,000 cubic feet, then 23.35 square

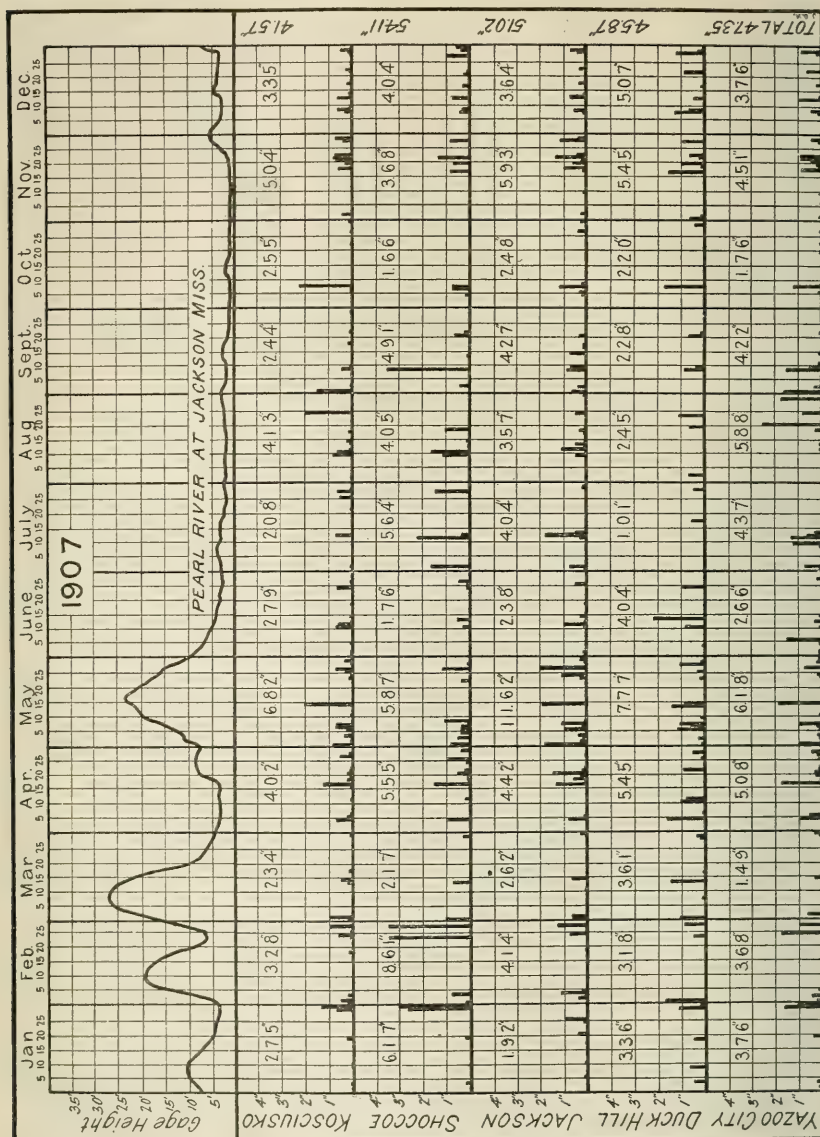


Fig. 3f.—Hydrograph of Pearl River and daily precipitation in vicinity of Big Black River, 1907.

units represent a total of 64,500,000,000 cubic feet of run-off for the period from the watershed area of 3,120 square miles, which is equivalent to a total run-off of 8.9 inches in depth.

The average rainfall on the watershed for this period, as recorded at the Weather Bureau stations at Louisville, Kosciusko, and Jackson,

was 16 inches. To this rainfall is attributed the 8.9 inches of run-off computed above. The run-off was therefore equivalent to 55.6 per cent of the rainfall.

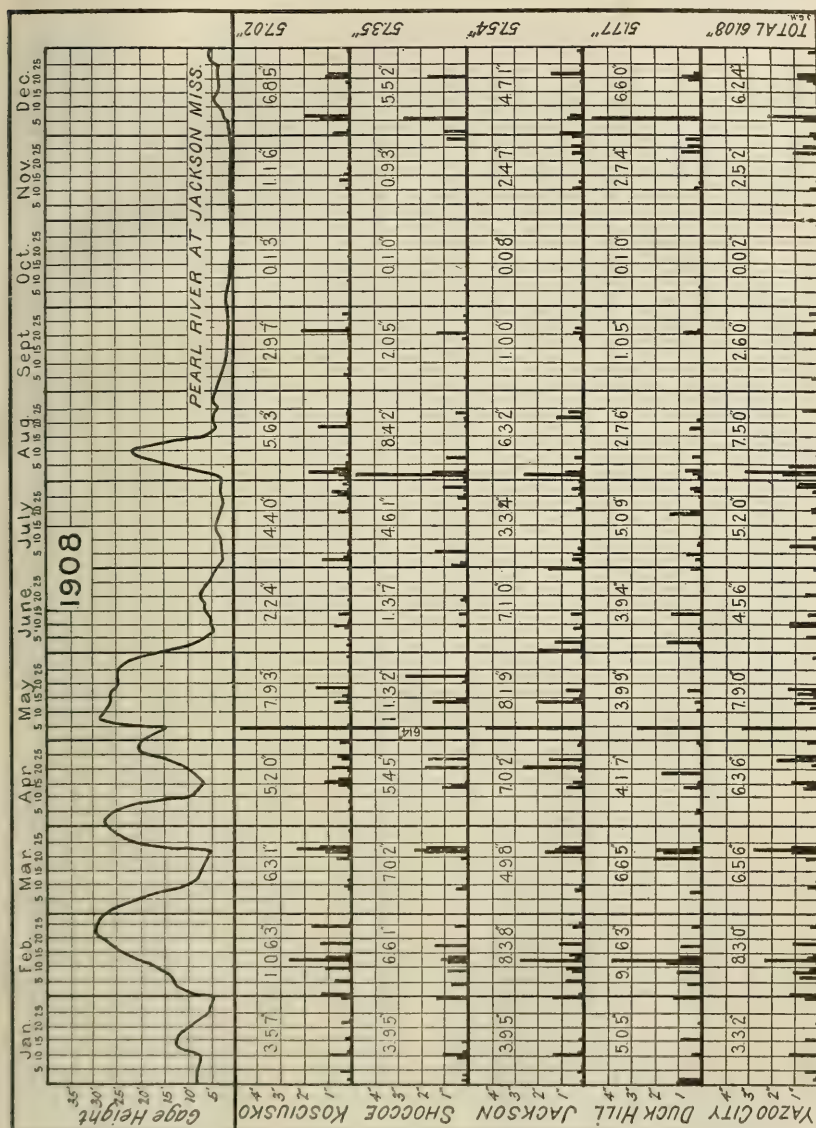


Fig. 3g.—Hydrograph of Pearl River and daily precipitation in vicinity of Big Black River, 1908.

In a similar manner the hydrograph of the Pearl River was plotted for March, April, and May, 1902, and is shown in figure 4, B. The rainfall records for this period show an average total precipitation of 13.1 inches at Jackson and Louisville, no records being available for Kosciusko. The total run-off to this rainfall, as obtained from the

hydrograph, was 53,353,000,000 cubic feet, which is equivalent to 7.35 inches in depth over the entire watershed. These figures indicate that the run-off during the spring flood of 1902 amounted to 56.1 per cent of the rainfall.

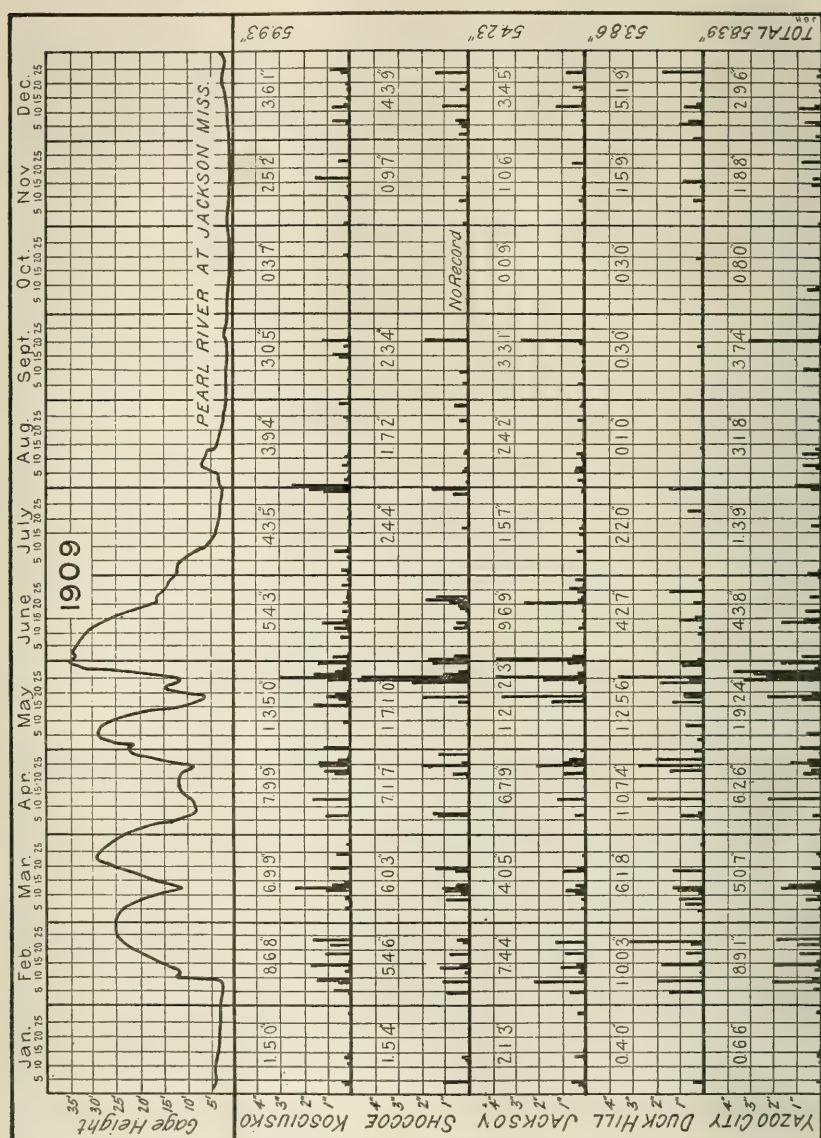


FIG. 3h.—Hydrograph of Pearl River and daily precipitation in vicinity of Big Black River, 1909.

The method employed for obtaining the probable maximum rate of run-off involves the determination of the following:

(1) The approximate time required for the maximum flood-producing storm to raise the river from a low stage to a maximum stage at the gauging station, when no storage exists,

(2) The approximate time required for the river to fall from a maximum to a low stage when no storage exists.

(3) The probable shape of the hydrograph as determined from a consideration of (1) and (2).

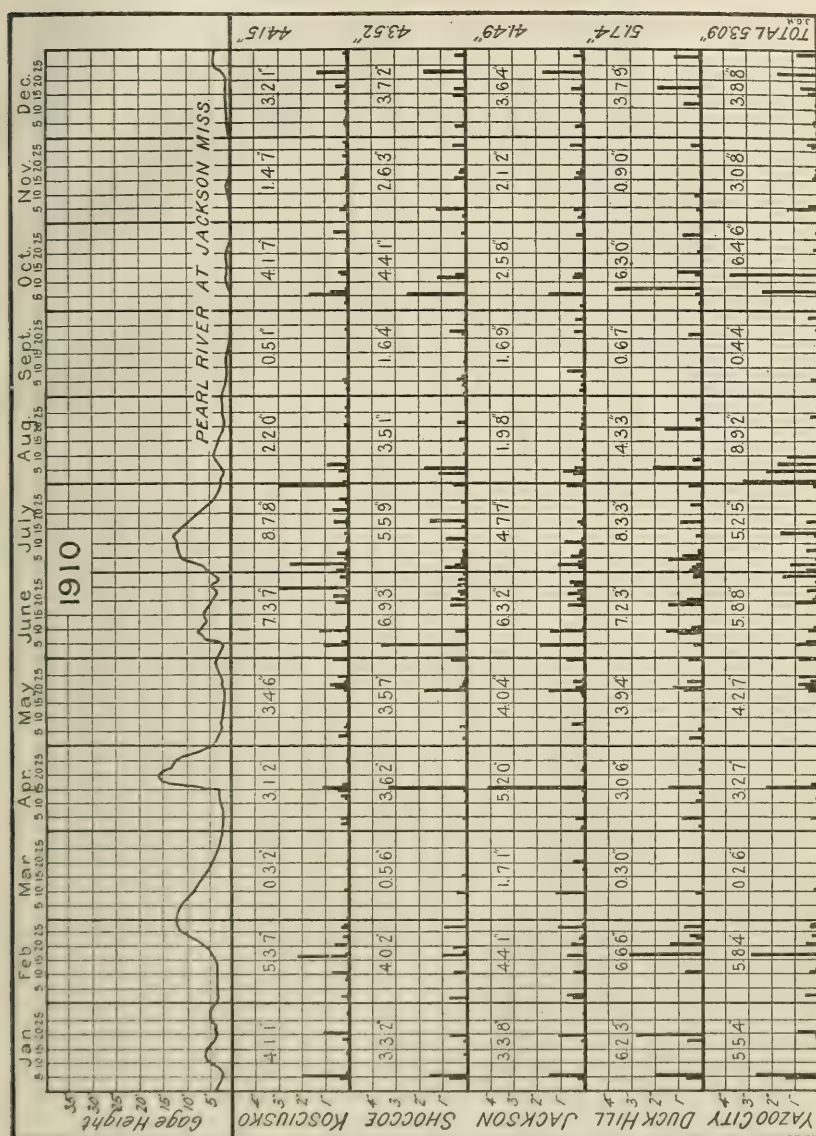


FIG. 31.—Hydrograph of Pearl River and daily precipitation in vicinity of Big Black River, 1910.

(4) The total run-off for the entire flood period.

(5) The probable run-off due to rains occurring after the maximum stage is reached.

(6) The amount of run-off which would produce the maximum stage as determined by deducting (5) from (4).

(7) The probable maximum rate of run-off as determined from a hydrograph constructed according to (3) and (6).

The time required for the Pearl River to rise is shown by the line *a b* in figure 4, A and B, and was about six days in each case. It

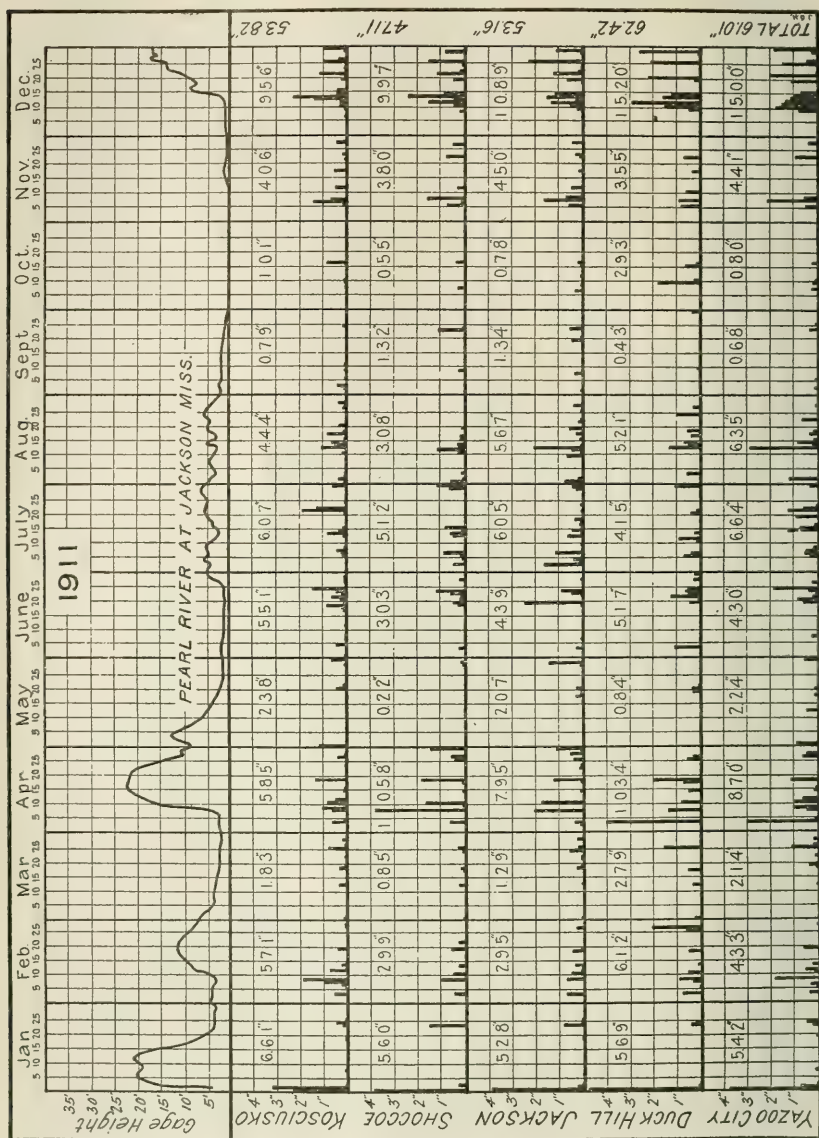


FIG. 31.—Hydrograph of Pearl River and daily precipitation in vicinity of Big Black River, 1911.

would be impossible to predict precisely the effect of improved drainage conditions upon this interval of time, but owing to the increased velocity of flow in the channel a less time would be expected, and in the computations this time will be taken as five days.

A study of the hydrographs of numerous streams tends to show that when practically no storage exists and when no rains occur just before, at, or after the maximum river stage, the time required for a stream to rise is approximately equal to the time consumed in falling. Owing

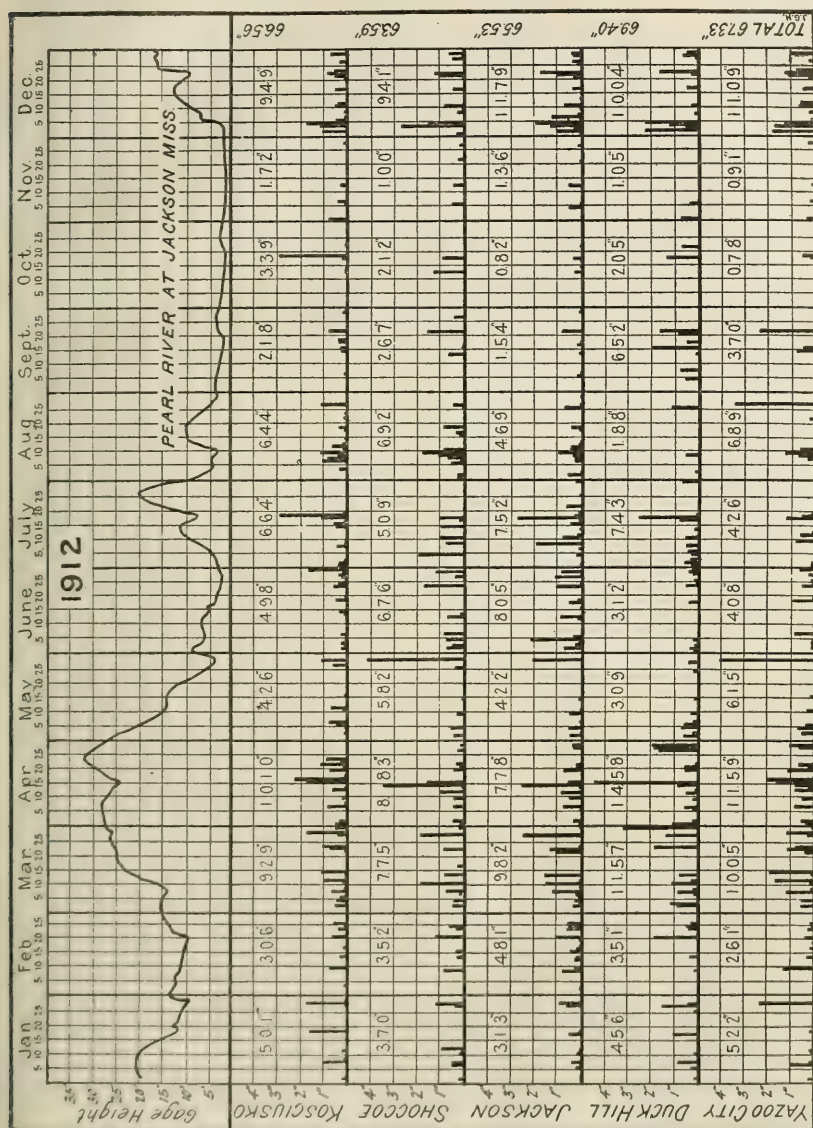


Fig. 3k.—Hydrograph of Pearl River and daily precipitation in vicinity of Big Black River, 1912.

to the lack of definite knowledge as to the storage and rainfall conditions on most streams, it is difficult to obtain accurate information on this point, but it is believed that the table following shows in a general way the truth of this statement.

Time of rising and falling of streams under minimum storage conditions as indicated by hydrographs resulting from practically continuous rains before but unaffected by rainfall after maximum stage was reached.

Name of river.	Observation station.	Date of maximum stage.	Time rising.	Time falling.	Maximum stage.	Flood stage.
			<i>Days.</i>	<i>Days.</i>	<i>Feet.</i>	<i>Feet.</i>
Tombigee.....	Columbus, Miss.....	Apr. 20, 1893	6	6	17.5	33
Do.....	do.....	Feb. 29, 1908	3½	4	10	33
Do.....	do.....	Mar. 28, 1908	7	6½	21	33
Do.....	do.....	July 13, 1910	5½	5½	19	33
Do.....	do.....	Apr. 24, 1911	5	5	26	33
Do.....	Aberdeen, Miss.....	Dec. 9, 1912	5½	6½	25.5	33
Do.....	do.....	Apr. 11, 1911	5	5	32	33
Do.....	Cochrane, Ala.....	Apr. 27, 1911	4½	5	31.5	41
Do.....	Fulton, Miss.....	Apr. 19, 1910	3	3	10	17
Do.....	Demopolis, Ala.....	Nov. 30, 1899	7	7	16.5	35
Do.....	do.....	Feb. 9, 1907	8	10	45	35
Do.....	do.....	Dec. 27, 1908	3½	4	25	35
Do.....	do.....	June 27, 1909	5	5½	42	35
Do.....	do.....	July 22, 1912	3	3	17.5	35
West Pearl.....	Pearl River, La.....	May 28, 1910	6	6	12.8	12
Savannah.....	Augusta, Ga.....	July 15, 1905	5	5	20.7	32
Flint.....	Montezuma, Ga.....	Feb. 15, 1905	5½	5½	20.7	20
Pea.....	Pera, Ala.....	Feb. 16, 1905	8	9	29.4	-----
Total.....	-----	-----	96	101½	-----	-----

The above table indicates that the time of falling is slightly greater than that consumed in rising, as may be seen by comparing the total number of days in each case. However, in the method under discussion, if the time of falling be taken equal to that of rising the result will tend toward a run-off rate that is too large rather than too small, and there will thus be introduced a factor of safety which is especially desirable in planning levee systems. Therefore, in the following computations the assumption is made that the time of falling after the maximum rate of run-off is reached will be the same as the time of rising, and that a uniform rate of rising and falling is maintained, the latter assumption also being on the side of safety.

If a hydrograph of the Pearl River for the storm period of 1902 be constructed, showing the river to perform in accordance with the foregoing conditions, it would consist of a triangle whose base represents 10 days, as shown by the line *au* in figure 4, B. The lower portion of the hydrograph would probably conform quite closely to the curve *un* whose rate of falling is slightly greater than that indicated by curves representing this stage of subsidence during other periods. Thus the hydrograph *afunr* would represent the performance of the stream from March 26 to May 12 under improved drainage conditions, and assuming that no rainfall occurred which affected its decline.

The total run-off for the storm period of 1902 is represented by the area *maoqs* as shown on the actual hydrograph of the Pearl River. An inspection of this hydrograph shows the decline of the river to have been materially affected by rainfall after April 1, which

inference is substantiated by reference to the rainfall records. Since this rainfall would not affect the maximum stage of the assumed hydrograph *afunr*, its run-off should be deducted from that of the entire period. The run-off due to this rainfall can be approximately

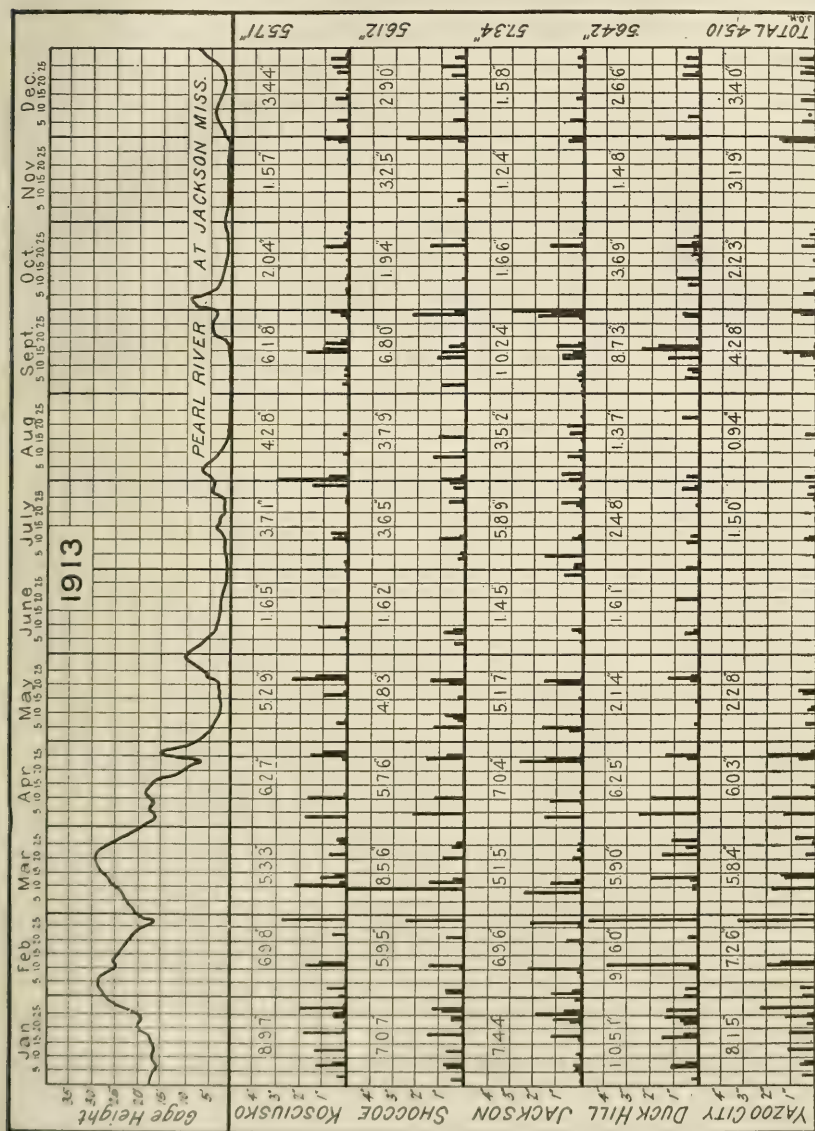


Fig. 31.—Hydrograph of Pearl River and daily precipitation in vicinity of Big Black River, 1913.

ascertained by applying the percentage of rainfall flowing off, as heretofore computed, to the total amount of rainfall occurring between March 30 and May 10. The average total rainfall at Jackson and Louisville from April 5 to May 10 was 3.9 inches. The portion

of the rainfall flowing off was, as previously calculated, 56 per cent for this storm period. Fifty-six per cent of 3.9 inches is 2.18 inches, or 15,950,000,000 cubic feet. The run-off which produced the maximum rate is equal to the total run-off, represented by the area *maogs*, minus the above computed amount and should be equivalent to the area *mafunrs* under the hydrograph as constructed for improved conditions.

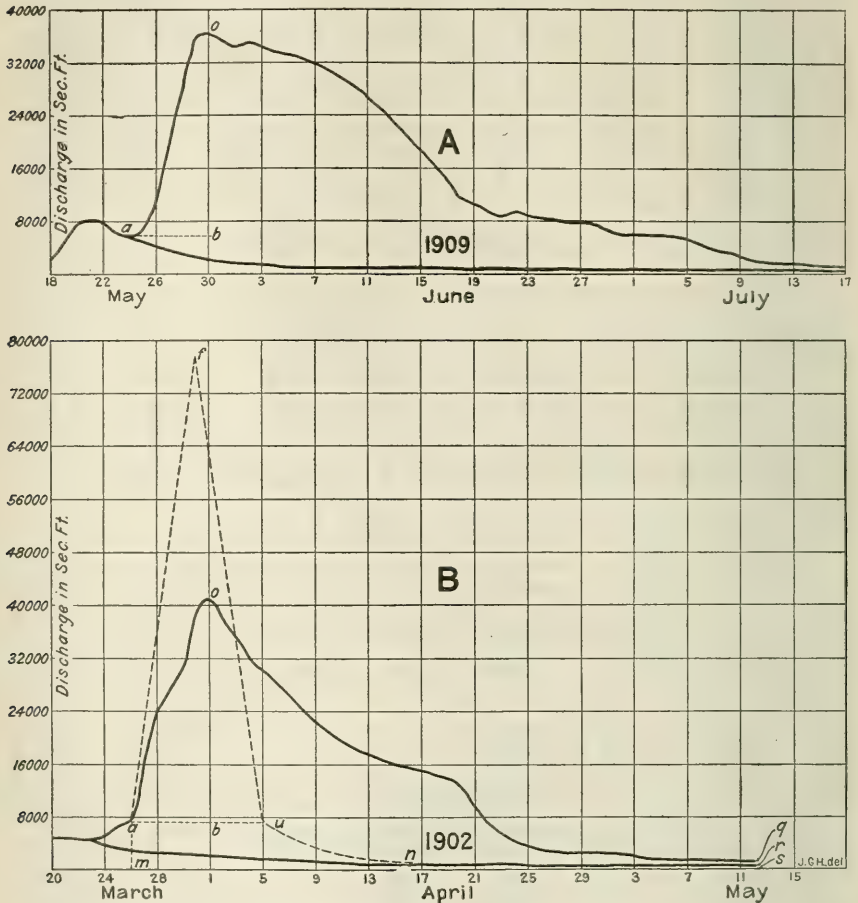


FIG. 4.—Discharge hydrograph of Pearl River at Jackson, Miss.

It can be seen from the figure that the area *maunrs* is common to each of the two distinct hydrographs for actual and improved conditions. Therefore the run-off to be provided for by the triangle *afu* must equal the run-off in the area *aoqrnu*, minus the above amount to be deducted for rainfall occurring subsequent to April 5. The area *aoqrnu* equals 16.76 square units, or 46,350,000,000 cubic feet, which diminished by 15,950,000,000 equals 30,400,000,000 cubic

feet of run-off to be provided for by the area included in the triangle *afu*. Since the base of this triangle was shown to represent 10 days (864,000 seconds), and its area must equal 30,400,000,000 cubic feet of run-off, the altitude must be equal to

$$\frac{2 \times 30,400,000,000}{864,000} = 70,400 \text{ second feet.}$$

The maximum ordinate of the area *maunrs* is 7,200 second-feet. The maximum rate of run-off is measured by the ordinate from the apex of the triangle to the horizontal axis of the figure and is equal to the sum of 70,400 and 7,200 or 77,600 second-feet, which is equivalent to 24.8 second-feet per square mile of watershed area. In view of the fact that the upper portion of a discharge hydrograph is generally rounded off and therefore does not conform to the apex of a triangle, the 0.8 second-feet is dropped. Thus 24 second-feet per square mile is the probable maximum rate of run-off to be expected from a drainage area of 3,120 square miles on the Pearl River under improved conditions.

RUN-OFF FROM SMALL AREAS.

In determining the probable maximum rate of run-off for areas on the Big Black River that are smaller than the one just considered, it was necessary to rely entirely upon the rainfall records, since no satisfactory run-off data are available for comparison. This involves consideration of the following three essential factors: (1) The time required for water to flow from the most remote part of the watershed to the lower end or point of discharge; (2) the maximum rate of rainfall of a duration equal to this time; and (3) the percentage of rainfall flowing off.

The rainfall records of Kosciusko and Duck Hill, Miss., are applicable to the upper end of the Big Black watershed, comprising an area of 1,200 square miles. This area is about 85 miles long and has an average width of 14 miles. The profile of the Big Black River Valley (fig. 11) shows the average slope of this section to be approximately 1.6 feet per mile. If it be assumed that a floodway with an average depth of flow of 6 feet is to be constructed for 75 of the 85 miles, the velocity of flow computed by the Chezy formula, with *n* equal to 0.040, would be 2.2 feet per second, or 1½ miles per hour for maximum flow. Since the depth of water in the floodway will increase from a low to a high stage, the velocity will be less during the earlier part of the storm, and it would therefore be reasonable to reduce the above-computed velocity, say, to 1¼ miles per hour. Then the time required to flow the 75 miles would be 2 days and 12 hours. The water from the outer edge of the watershed must flow from the hills to the bottoms. Considering the tortuous path the water must

follow, a rough estimate of the distance would be 20 miles, and assuming a velocity of $1\frac{1}{4}$ miles per hour, the time required for the water to flow this distance would be about 16 hours. Hence the total time required for the water to flow from the upper edge of the watershed to the lower end of the area under consideration would be 3 days and 4 hours. According to factor (2) a rain of 3 days' duration will produce a maximum rate of flow from the total area.

In the consideration of drainage areas of about 100 square miles the probable maximum rate of run-off from Apookta Creek was investigated in conjunction with the rainfall records at Kosciusko, this rain-gauge station being in the neighborhood of Apookta Creek. The drainage area for this creek is 102.5 square miles and is approximately 10 miles long and 10 miles wide. Employing the same method as in the foregoing case, the time element was obtained by estimating the distance at 30 miles and the velocity at $1\frac{1}{4}$ miles per hour, which gives 24 hours as the time required for the water to traverse the watershed.

As previously explained, the run-off from the Pearl River watershed for the two maximum storms was 55.6 and 56.1 per cent. Actual gaugings of the flow in Twenty-Mile Creek, near Baldwyn, Miss., were made by C. E. Ramser, who determined the run-off from the drainage area of 80 square miles to have been 1.17 inches from a storm of 1.88 inches in April, 1913. In that instance the run-off was 62.3 per cent. These data justify to a certain extent the assumption here made that approximately 60 per cent of the total rainfall will run off. Then, assuming as before that for any flood the rising and falling stages will be of equal duration and at a uniform rate, it can be shown that the maximum daily rate of run-off will be 60 per cent of the average daily rainfall for the maximum storm of duration equal to the period of rising flood.

The rainfall records (fig. 3 a to 3 l) show the greatest three-day rain since 1903 on the 1,200 square miles at the upper end of the Big Black River watershed to have occurred in May, 1909 (fig. 3h), the average total precipitation for the two stations having been 5.85 inches, or 1.95 inches per 24 hours. If 60 per cent of the rainfall be assumed to flow off, then the probable maximum rate of run-off would be 60 per cent of 1.95 inches, or 1.17 inches per 24 hours, which is equivalent to 31.5 second-feet per square mile for the area of 1,200 square miles. The maximum rainfall of one days' duration for Apookta Creek, as taken from the records at Kosciusko (fig. 3b), was 5.8 inches, this rain having occurred February 6, 1903. Assuming 60 per cent of the rainfall to flow off, the probable maximum run-off for 24 hours will be 3.48 inches, which is equivalent to 93.7 second-feet per square mile.

APPLICATION OF RUN-OFF RESULTS.

The following is a summary of the results obtained for the three drainage areas discussed:

Drainage area.	Probable run-off.
<i>Square miles.</i>	<i>Second-feet per square mile.</i>
3,120	24.0
1,200	31.5
100	93.7

In order to utilize these results as a basis for determining run-off from other areas, it is necessary to incorporate them into a formula which will give the probable run-off from any desired drainage area. A formula of the Murphy type seems best adapted to the use of the above data.

The Murphy formula is

$$Q = \frac{46790}{M + 320} + 15$$

in which Q equals the discharge in second-feet from each square mile, and M the watershed area in square miles. Adopting a general formula of the above form, viz.,

$$Q = \frac{X}{M + Y} + Z$$

the values of X , Y , and Z were derived by substituting for Q and M the following values obtained for the Big Black watershed:

Where $M = 100$, $Q = 95$

Where $M = 1200$, $Q = 32$

Where $M = 3000$, $Q = 24$

Substituting the above values, and solving, the following formula was obtained:

$$Q = \frac{18700}{M + 144} + 18$$

For convenience in the use of this equation its curve has been platted (fig. 5). It is believed that this curve represents the maximum rate of run-off that may be expected under improved conditions, and the design of all levee improvements has been based upon it, although no rate of run-off greater than 90 second-feet per square mile has been used.

If a levee system be insufficient to care for the flood conditions, great damage may be done to the land presumed to be protected and to the levees themselves; great care should therefore be taken to provide for maximum run-off conditions. On the other hand, if a

ditch be designed to care for only the ordinary floods, it prevents a large number of overflows and aids materially in reducing the maximum floods. The cost of ditches designed on this basis will be much less than that necessary to care for the maximum conditions, while the

land will be greatly benefited by the decrease in the number, durations, and heights of the floods.

Investigations by C. E. Ramser, in Lee County, Miss., where conditions are quite similar to those existing in the Big Black watershed, seem to show that a ditch that has a capacity sufficient to care for a run-off of 55 second-feet per square mile for an area of 25 square miles, and a capacity of 25 second-feet per square mile for an area of 100 miles, is sufficient to handle a large number of the floods such as formerly had occurred, and to reduce greatly the heights and durations of the maximum floods. Believing that a design fulfilling these conditions is economical in this case, the

following formula of the Murphy type has been developed by the use of the above values.

$$Q = \frac{1000}{M} + 15$$

The curve for this equation has been plotted by substituting various values for M and

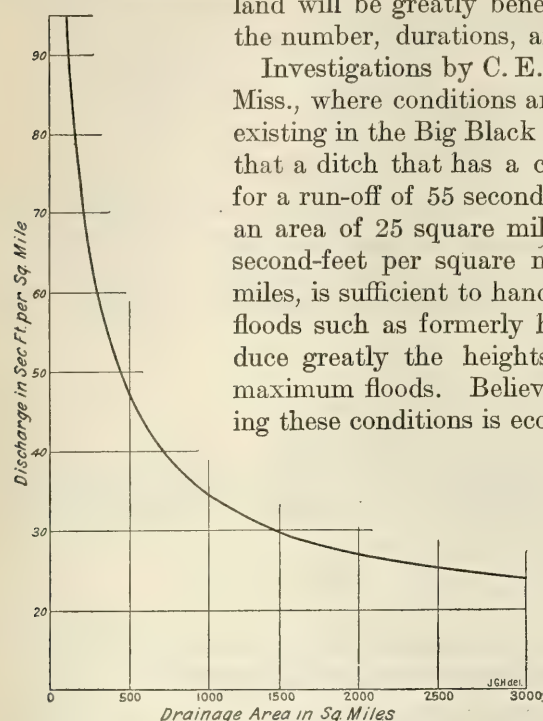


FIG. 5.—Discharge curve used in design of levees, Big Black River, Miss.

solving for Q ; this curve (fig. 6) has been used in computing the sizes of all ditches, except that no ditch had been designed for a greater run-off than 70 second-feet per square mile.

DRAINAGE PLANS CONSIDERED.

Before the final plan, as hereafter discussed, was decided upon, other possible methods of reclamation were carefully investigated and compared. These are very briefly discussed below.

IMPROVING PRESENT CHANNEL.

The plan of clearing the present river channel and making cut-offs was first investigated. It was found that the channel, even if it were straightened throughout and cleared of all drifts and brush, would not have sufficient capacity to care for the run-off as indicated by the curve for ditches (fig. 6), and that such improvements would not reduce the flood height sufficiently to prevent the summer and fall overflows, which are very injurious to the crops.

RELIEF DITCH.

A relief ditch was then laid out in such a manner that two separate channels could be maintained the entire length of the bottom below Bywy Creek. Owing to construction limitations the maximum section of this ditch was designed with a bottom width of 100 feet and a depth of flow of 13 feet. With this ditch and with the river channel cleared, the run-off, as computed by the ditch formula, could be cared for above the mouth of Poplar Creek; but from this point downstream it is believed that the relief obtained would not justify the expenditure. The estimated cost of this plan, including the construction of the ditch and the clearing of the old channel, amounted to \$27 per acre of land benefited.

LEVEE AND FLOODWAY PLAN.

Preliminary computations were then made on a system of protection consisting of levees and floodways. The necessary widths of river floodway and heights of levees were determined. Interior drainage was provided for by ditches with outlets through floodgates to the river channel. The results obtained show that while the cost of the complete system will be high, considering present land values and economic conditions in the district, yet portions of the valley can be reclaimed at a reasonable cost even at the present time, and the remainder can be reclaimed at a later date as conditions justify. Plans and estimates were therefore made along the lines just described; these are discussed in some detail in the following pages.

PROPOSED PLAN.

The general plan as proposed for the drainage of the Big Black River bottoms consists of:

- (1) The construction of a main ditch and of the necessary laterals at the upper end of the valley.
- (2) The construction of levees.
- (3) The clearing of a floodway through the bottoms, including the present river channel.
- (4) Provision for interior drainage by the construction of ditches and the clearing of present channels.

The proximity of the river channel to the bluffs or higher land at frequent intervals and the entrance of tributaries into the bottoms divide the overflowed land into natural drainage units. From the Mathiston-Walthall Road to Cox Ferry 36 drainage districts have been planned. These districts, as well as the drainage improvements recommended, are clearly shown on the accompanying maps and profiles (figs. 10-12, in pocket at end of bulletin).¹

¹ For index map to figure 10, see figure 2.

METHODS OF COMPUTATION.

In computing the sizes of ditches and levees and the capacities of the floodways, the Chezy formula, $v = c\sqrt{rs}$, was used. In this formula c is a coefficient depending upon channel conditions and determined by Kutter's formula, in which the coefficient of roughness, n , was taken at 0.030 for ditches, 0.035 for cleared channels, and 0.040 for floodways.

To provide a margin of safety, ditches were given a depth of 1 foot greater than that computed as necessary to handle the discharge. The tops of the levees were taken at 3 feet above the high-water line as computed.

In determining the capacity of the floodway it was necessary to consider its cross section in two parts, owing to the fact that in many of the bends of the channel the water will flow in a direction opposite to that in the floodway. Such a condition is shown at *a* in figure 7.

The friction existing between the two bodies of water flowing in opposite directions is without doubt less than that between the water and the ground surface in the floodway; hence it should be safe to compute the discharge of the floodway as though the channel did not exist, adding thereto the

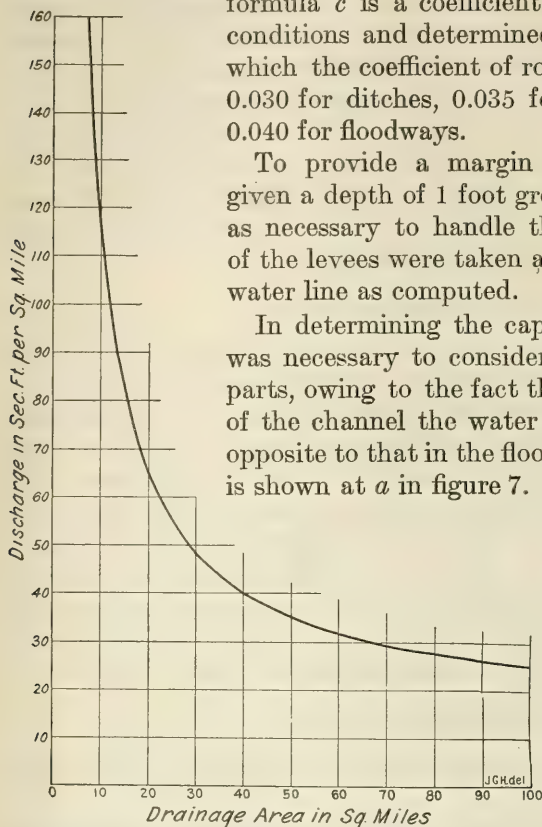


FIG. 6.—Discharge curve used in design of ditches, Big Black River, Miss.

discharge of the channel to obtain the total capacity of the floodway. The capacity of the section *efgh* (fig. 8) was computed by using the slope of the river channel, and taking n equal to 0.035; whereas in determining the capacity of the section *abcd* the slope used was that of the valley, and n was taken as 0.040. By adding the two results the total capacity of the floodway was obtained.

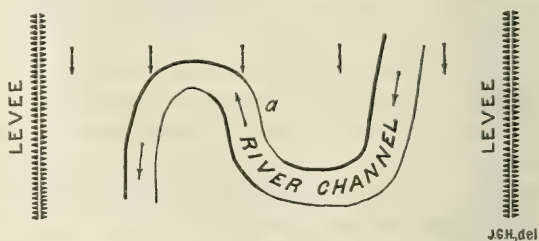


FIG. 7.—Sketch showing directions of flow in floodway, Big Black River, Miss.

In computing the capacities of the creek floodways, where the ditches parallel the levees, the discharge of the section represented by *befghk* (fig. 9) was computed by taking the line *fghk* as the wetted perimeter for the area, and *n* equal to 0.030. The discharges of the areas *abkl* and *cdef* were then computed, taking *n* equal to 0.040; the sum of these three results gave the total capacity of the floodway.

CONSTRUCTION.

No attempt is made here to provide full specifications for the proposed work. It is intended under this caption merely to point to

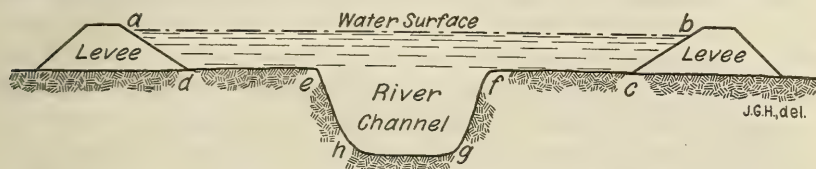


FIG. 8.—Sketch illustrating method of computing capacity of river floodway, Big Black River, Miss.

some of the more important details that have governed the design of the improvements and to emphasize those features of location and construction which are vital to the success of the system.

DITCHES.

The minimum ditch planned has a bottom width of 6 feet, side slopes of 1 to 1, and a depth of flow of 6 feet; such a ditch can be constructed economically with the same type of machine that builds the

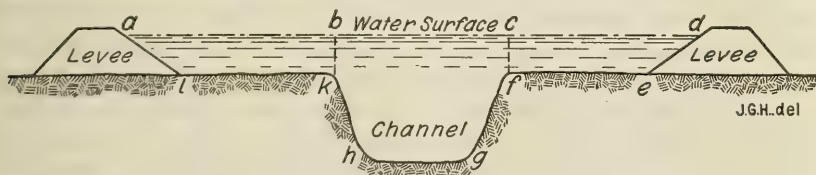


FIG. 9.—Sketch illustrating method of computing capacities of creek floodways, Big Black River, Miss.

levees. Ditch No. 4, in district No. 1, can be constructed economically by a floating dredge because its size is sufficient to justify installing such a machine. The width of the berm is independent of the width of the ditch, but varies with the depth of excavation. For cuts of 10 feet or less a berm of 10 feet is planned; for cuts greater than 10 feet a berm of 12 feet is recommended.

In existing channels, where clearing is the only improvement needed, all timber and underbrush should be cut, all debris removed, and all stumps cut level with the ground. The widths of right-of-way for ditches were computed by taking $3\frac{1}{2}$ times the width of the top, plus the width of both berms.

LEVEES.

The ground should be carefully inspected to secure the best location. The locations as shown on the map may be varied from whenever by so doing advantage can be taken of higher or firmer ground. In no case should a levee be located less than 200 feet from the bank of the river, and care should be taken to protect the levees against washing or undermining at the sharp bends of the stream. Changes in direction should be made by easy curves rather than by sharp angles.

The base should be cleared of all vegetation and stumps, and the large roots removed. For levees more than 10 feet high a muck ditch about 3 feet deep and 6 feet wide should be dug along the center line of the embankment. This ditch may be filled as is any other portion of the levee. The surface of the ground on which the levee is to be built should be broken with a plow, so that a bond will be formed which will prevent seepage from following the surface between the old and the new material.

The soil of which the levees are to be built is a heavy river silt or clay and will form a strong and fairly impervious embankment. The durations of the extreme high-water stages will be short, so that the levees will not ordinarily be saturated for more than a few feet from the ground surface. The estimates for the levees have therefore been based on a top width of 4 feet, side slopes of $2\frac{1}{2}$ to 1 on water side and $1\frac{1}{2}$ to 1 on land side for river floodway levees, and 3 to 1 on water side and 2 to 1 on land side for the creek floodway levees. This difference in slopes is recommended because of the fact that the creek floodway levees will be subjected to a current of greater velocity than will those of the river floodway.

The levees should be built of clean earth that is free from vegetable matter taken from the side of the levee next to the waterway. The pits from which the earth is taken should have side slopes at least as flat as 1 to 1; and if practicable should not be more than 6 feet deep. Along the river levees a berm or strip of land at least 10 feet wide, from which no earth has been taken, should be left between the pit and the toe of the levee. For the creek floodway levees the berm should be 50 feet wide and the borrow pit of the shape specified. The widths of right of way for levees were computed by adding to the width of base and berm, the width of borrow pit, based upon a depth of 6 feet and side slopes 1 to 1.

The material can be most economically handled by a dry-land excavator of some type that will take the material from the pit and place it in the levee at one operation. When the required amount of material is in place, the top and sides of the embankment should be smoothed to an even surface and the whole planted in any grass adapted to the soil and climate.

FLOODWAYS.

In floodways all trees and underbrush should be cut and removed and all drift disposed of; stumps should be cut level with the ground. The heights of the levees have been computed upon a basis which requires that everything that will seriously impede the flow of water shall be removed from the floodway, the latter including the river channel itself; the widths to be cleared are given in Appendix II.

It is recommended that a separate organization be formed to clear the entire river floodway, since, to be effective, this must be cleared through the length of the levee improvements. It is not believed that the clearing can be advantageously handled by the separate levee districts, working independently. To clear this floodway, the entire valley between the lower end of district No. 1 and Cox Ferry should be organized into one drainage district. The cost of the work should be assessed, according to the benefits to result, to all of the land that at present is subject to overflow, excepting that within the floodway itself. The floodway should be cleared to a point 2 miles below Cox Ferry in order to prevent the increase of flood height at the Ferry that otherwise would result from the more rapid discharge of the upper river.

SEDIMENTATION AREAS.

The smaller streams and ravines which enter the valley from the surrounding hills usually carry a large amount of sediment and drift, which being deposited is continually filling up the lands where the streams enter the bottoms. For this reason many of these smaller streams have not established channels for themselves, but have filled up and spread over the bottom. If ditches are constructed to connect these small streams with the main drainage channels, the same process of sedimentation will continue and the ditches will soon become filled.

To overcome this difficulty in the ditches that are to be constructed, it will be necessary to provide sedimentation areas, each bounded by a levee on the lower or downstream side that will serve to impound the water and decrease its velocity, thus causing the suspended matter to be deposited. In this manner the excess sediment and drift can be confined to a limited area and damage to ditches prevented. When an area has become filled to such a height that storage is no longer possible, a new levee can be constructed a little farther upstream or downstream; thus a new sedimentation area is formed, leaving the old one, filled with fertile soil, available for cultivation.

These areas are of the utmost importance in the reclamation of a river valley of the character of that of the Big Black, and as they make it possible for the farmer to retain the most fertile soil on his farm, they should be constructed by him regardless of whether the larger

drainage work is carried out or not. As these sedimentation areas will in most cases be outside the district boundaries, no estimates of cost have been made for them.

The sediment carried by these tributaries originates for the most part in the erosion of the surrounding hills. Too much stress can not be laid on the importance of controlling this action by proper terracing of slopes. It should be realized that it is the most fertile particles of soil that are thus carried away, not only to the detriment of the land, but to the great damage of the drainage channels in which the sediment is deposited.

COST OF IMPROVEMENTS.

In the estimates for the construction of ditches and levees the cost of clearing right of way is provided for in the price per cubic yard for excavation.

It is believed that the ditches can be excavated at an average cost of 9 cents per cubic yard. Levees with berms of from 10 to 15 feet are estimated at 13 cents per cubic yard, and those with berms of 50 feet at 18 cents per cubic yard; in both cases the earth is assumed to be measured in excavation. The increased unit cost of the levee work over that for the ditches is due to the greater cost of depositing all of the earth on one side of the ditch or borrow pit, and to the cost of leveling and smoothing the bank. Where a 50-foot berm is specified a longer boom will be required than is necessary on the remainder of the work. This requirement, together with the greater distance which the earth must be moved, increases the fuel consumption as well as the time of construction.

In estimating the cost of floodgates, rough designs are made for three gates with capacities of 175, 525, and 1,400 second-feet, respectively, and the cost of each was determined on the basis of 1 per cent reinforced concrete construction, costing \$25 per cubic yard in place. The cost of all other gates were estimated by determining their required capacities, and interpolating between the three computed costs.

The cost of right of way for levees and ditches was estimated at \$10 per acre, no allowance being made for right of way for ditches which follow the present channels. The expense of clearing all brush, logs, and stumps from present channels was estimated at \$750 per mile.

It is not expected that it will be necessary for the organization to purchase the land to be cleared for the river floodway. Therefore this item is not included in the estimate. The cost of clearing the floodway is estimated at \$20 per acre, with an additional \$1 per acre for incidental expenses. The timber cut should remain the property of the landowner.

An addition of 10 per cent on the estimated cost of the improvements is made to cover legal, engineering, and other incidental expenses. A detailed estimate of cost is given in the table on page 33.

Estimate of cost, by districts.

District No.	Assess- able area.	Excavation.				Channel clearing.		Right of way.			Flood- gates.		Legal, engine- ering, and con- tin- gent ex- penses, at 10 per cent.	Total cost. ¹	Cost per acre. ¹	Remarks.	
		Ditches.		Levees.		Length.	Cost at \$750 per mile.	For ditch- es.	For lev- ees.	Total.	Cost at \$10 per acre.	No.					Cost.
		No.	At 9 cents.	Cost.	At 13 cents.													Cost.
Acres.		Cu. yds.	Cu. yds.	Cu. yds.	Cu. yds.	Miles.	Acres.	Acres.	Acres.	Acres.	Acres.						
1	14,233	42,292	930	\$200 15¢	21,320	93,470	86,990	682	57	662	\$6,620	800	2,467	\$20,677	\$227,451	\$15.99	
2	1,728	1	177,520	15,977	21,320	71,900	44,390	33	57	90	900	1,000	2	56,319	27,140	13.72	
3	5,643	4	86,140	7,753	241,930	71,900	44,390	35	122	177	1,770	1,000	3	3,060	61,951	23.43	Jack Slough to be cleared.
4	1,421	1	11,460	1,031	234,800	71,900	29,224	7	63	70	700	1,000	3	35,030	38,583	27.12	icky Slough to be cleared.
5	1,540	1	41,700	3,701	193,410	116,500	25,143	28	56	84	840	1	750	30,494	33,943	21.78	
6	1,778	2	35,600	3,204	169,980	116,500	43,067	22	126	148	1,480	2	1,500	49,251	4,925	54,176	30.47
7	1,138	1	208,900	208,900	208,900	208,900	27,105	39	59	98	980	1	900	31,220	34,342	20.88	
8	1,553	1	61,500	5,535	45,050	166,700	35,941	34	90	94	940	1	750	43,166	4,317	47,483	29.88
9	1,853	2	55,520	4,997	195,870	35,941	25,463	32	54	86	860	2	300	33,620	3,362	36,982	19.96
10	1,325	1	82,580	7,430	187,850	35,941	24,421	43	53	96	960	1	1,300	34,111	3,411	37,522	24.60
11	1,997	3	78,240	7,042	268,820	39,520	42,035	46	86	131	1,310	3	3,300	53,687	5,369	59,056	29.57
12	1,088	1	19,200	1,728	226,360	37,520	33,180	12	47	59	590	2	1,650	27,148	2,715	29,863	27.20
13	1,948	2	96,070	8,646	253,740	37,520	32,986	54	68	122	1,220	1	2,000	44,052	4,405	48,457	24.25
14	1,015	1	34,350	3,092	156,960	37,520	20,405	21	41	62	620	1	900	25,017	2,502	27,519	27.11
15	1,169	1	63,470	5,712	200,440	37,520	26,057	34	52	86	860	1	750	33,379	3,338	36,717	24.17
16	1,519	3	186,500	16,785	357,440	37,520	24,467	74	145	219	2,190	3	6,400	101,817	10,182	111,999	18.16
17	6,169	1	195,350	17,832	262,890	37,520	34,111	68	141	210	2,100	1	3,500	56,873	5,687	62,560	24.12
18	1,418	1	155,300	13,971	372,550	18,440	51,751	73	69	102	1,710	2	2,750	70,188	7,019	77,207	23.80
19	3,244	1	155,300	13,971	372,550	18,440	51,751	73	69	102	1,710	2	2,750	70,188	7,019	77,207	23.80
20	6,013	2	262,640	23,638	480,000	48,000	62,400	105	133	238	2,380	2	4,200	93,068	9,307	102,375	17.03
21	1,860	1	94,850	8,537	246,800	45,000	40,184	46	93	139	1,390	1	2,000	51,311	5,131	56,442	30.35
22	2,521	1	21,570	1,941	308,900	45,000	40,157	13	79	92	920	3	2,500	48,443	4,844	53,287	21.14
23	5,671	3	261,310	23,518	412,200	56,280	63,724	112	138	250	2,500	2	5,500	95,242	9,524	104,766	18.47
24	2,254	1	83,320	7,499	205,730	56,280	27,138	41	52	93	930	1	3,000	37,567	3,757	41,324	32.46
25	2,523	2	154,680	13,901	234,000	89,500	46,569	64	97	161	1,610	1	1,500	65,580	6,558	72,138	28.59
26	1,132	1	27,310	2,458	152,940	52,200	29,226	16	57	73	730	1	900	33,539	3,354	36,893	32.59
																	Panther Creek to be cleared be- low outlet of ditch A.

¹ Costs given do not include cost of clearing main floodway. This is estimated to cost \$494,970 (viz. 23,570 acres at \$21 per acre). This cost is assessed to the total area overflowed below district No. 1, less that of the floodway itself (viz. 118,570 acres less 23,570 acres=95,000 acres), making the cost per acre benefited, \$5.21.

Estimate of cost, by districts—Continued.

District No.	Assess- able area.	Excavation.						Channel clearing.		Right of way.				Flood- gates.		Legal, eng- neering, and con- tin- gent ex- penses, at 10 per cent.	Total cost.	Cost per acre.	Remarks.	
		Ditches.		Levees.				Length. Miles.	Cost at \$750 per mile.	For ditch- es.	Acres.	For lev- ees.	Acres.	Total. Acres.	Cost at \$10 per acre.					No. Cost.
		No.	At 9 cents.	Cost.	At 13 cents.	At 18 cents.	Cost.													
27	6,211	4	245,630	\$22,125	\$450,080	\$116,000	\$79,390	2.3	\$1,725	98	153	251	\$2,510	386,700	\$112,450	\$11,245	\$123,695	\$19.92	Sandy Run and outlet sloughs for ditches B and C to be cleared.	
28	1,035	1	50,300	4,527	185,190	57,690	34,459			26	54	80	800	1,200	40,986	4,099	45,085	43.56	Indian and Big Ditch Creeks to be cleared. Slough to be cleared.	
29	1,502	1	48,220	4,340	329,300	.....	42,809	.....	.....	28	77	105	1,050	1,900	49,099	4,910	54,009	35.96		
30	1,254	1	13,150	1,184	174,200	90,800	38,990	.....	.....	8	75	83	830	2,190	42,904	4,290	47,194	37.63		
31	6,541	3	174,550	15,710	740,760	35,970	102,773	2.8	2,100	84	188	272	2,720	6,111	135,053	13,505	148,558	22.71		
32	874	1	.....	.....	224,000	.....	29,120	1.6	1,200	.....	51	51	510	1,500	31,830	3,183	35,013	40.06		
33	1,927	1	97,860	8,807	279,640	.....	36,353	.....	.....	39	65	104	1,040	1,500	47,700	4,770	52,470	27.23		
34	2,444	2	94,550	8,510	439,250	.....	57,103	.....	.....	51	101	152	1,520	1,200	68,333	6,833	75,166	30.76		
35	1,238	1	45,660	4,109	253,800	.....	32,997	.....	.....	25	60	85	850	1,000	38,956	3,896	42,852	34.61		
36	713	.....	.....	.....	210,700	.....	27,391	.....	.....	.....	46	46	460	1,900	28,751	2,875	31,626	44.36		
96,088	55,528,290	475,480	9,236,190	1,017,350	1,383,819	31.3	323,475	2,054	2,842	4,896	48,960	59,82,500	2,014,234	201,423	2,215,657	23.06				

MAINTENANCE.

The most successful operation of any drainage system requires that it be maintained in the highest possible degree of efficiency. Where levees are involved, neglect may result not only in their destruction, but in great damage to crops, stock, and other property, and even in loss of human life. Each levee district should maintain an organization for systematic inspection and repairs. The levees should be periodically inspected in order that minor defects may be discovered and repaired.

To facilitate examination the levees should, where practicable, be kept in grass. Under no circumstances should their slopes be permitted to become covered with rank growths of vegetation that might obscure their weaknesses and the operations of burrowing animals.

Ordinarily, if minor defects be attended to promptly, levees will not require a heavy expense for maintenance. Floodgates should be examined after each heavy rain and great care taken to see that they are always in perfect condition and are unobstructed by débris or vegetation.

The maintenance of ditches consists largely in keeping them clear of vegetation and débris, so that the full, unobstructed channel will always be available. No bridges, fences, fish traps, or other structures should be permitted to interfere with the free flow of water.

The efficiency of the floodway will depend upon the degree to which they are kept clear of vegetation. This is especially true of the river floodway where the fall is slight. Periodical clearing will be necessary to prevent this waterway from reverting to its present obstructed condition.

SUMMARY.

The lowlands along the Big Black River, Miss., represent a condition that each year becomes more prominent in the South. Formerly, heavy growths of valuable timber afforded a revenue from the swamp and overflowed land; with the cutting of this timber, however, the land becomes valueless unless drained and put under cultivation.

Under present conditions from 75 to 100 per cent of the Big Black River bottoms are overflowed to a depth of from 3 to 8 feet by each heavy rainstorm that lasts from 2 to 3 days and covers the entire watershed. The problem is to restrict the area flooded and to reduce the durations of the overflows by promoting a quick passage of the flood water through the valley.

The plan for ultimate reclamation involves the excavation of a main ditch and laterals in the upper portion of the valley, and the construction of a leveed floodway throughout the remaining portion. Provision for tributary streams and for interior drainage is also made. To carry out this work, 36 drainage districts are planned, having a total area of 96,088 acres. The estimated cost of this

work, exclusive of that of clearing the main floodway varies in the different drainage districts from \$15.72 to \$44.36 per acre, the average cost per acre for the entire 36 districts being \$23.06. It is recommended that the clearing of the main floodway be done by a separate organization comprising all of the overflowed land below district No. 1, exclusive of that of the floodway itself. On this basis the cost of clearing would be \$5.21 per acre benefited.

Especial attention is called to the necessity of providing sedimentation areas at the lower extremities of the several tributaries of the river, and of taking immediate steps to arrest the hillside erosion now taking place within the watershed.

It is doubtful if conditions in the valley at this time justify the expenditure necessary for the complete reclamation as outlined, although at least one of the districts (No. 1) should be carried out at once. A feature that contributes greatly to the high cost per acre for the levee districts is the narrowness of the bottoms as compared with the large amount of water that must be provided for. It has seemed advisable, however, to prepare plans for the reclamation of the entire part of the valley under consideration, as the increasing demand for agricultural land will doubtless make the ultimate reclamation of these lands desirable.

In weighing the advantages of drainage as against the cost, the landowners should not lose sight of those benefits which may be termed secondary as distinct from those to which a direct money value can be assigned. First among benefits of this class should be placed the improved health conditions that follow improvements of this nature. Experience has also shown that the betterment of roads, made possible by drainage, results not only in greatly decreased cost of their maintenance, but also in the cheaper transportation of produce and in generally improved educational and social conditions in the community.

APPENDIX I.

BENCH MARKS.

Each bench mark listed below consists of an iron pipe $3\frac{1}{2}$ feet long and 3 inches in diameter, set in the ground to a depth of 3 feet. The top of pipe is covered with a bronze cap on which is stamped "Office Experiment Stations, U. S. Dept. Agr. Drainage" with elevation of top of bench mark to the nearest foot. Elevations refer to Gulf datum. A much greater number of bench marks were made by driving nails in notches cut in roots of trees, and in other ways. The locations and elevations of any of these may be learned by inquiry addressed to the Chief of Drainage Investigations, United States Department of Agriculture, Washington, D. C.

List of department bench marks.

Eleva- tion.	Location.
<i>Feet.</i>	
353.47	At Stewart, 100 feet north of center line of Southern Railway depot in public square.
311.55	At Kilmichael, west side Doris road, $\frac{1}{2}$ mile south of railroad crossing at bend in road, 10 feet north of 8-inch oak in northeast corner of pigpen.
345.33	At Vaiden, about 1,000 feet south of Illinois Central Railroad station and 100 feet south of railroad section house on west edge of railroad right of way, 10 feet north of cattle guard.
290.77	At West, 250 feet east of Illinois Central Railroad depot, in northwest corner of G. Millon's yard.
248.79	At Durant, 1,700 feet east of center line of Illinois Central Railroad, at foot of bluff on south side of public highway running east from Park Hotel.
234.60	At Goodman, 100 feet south of Illinois Central Railroad station, near west wall of brick store owned by Tate & Co.
231.30	At Pickens, 150 feet east of Illinois Central Railroad station, in northwest corner of hotel yard, 75 feet south of public highway crossing river bottom.
212.00	At Vaughan, 150 feet northwest of Illinois Central Railroad station, in northeast corner of J. L. Blakeman's yard.
204.47	At Hay, 150 feet northeast of Illinois Central Railroad station, in front of store owned by the Powell estate, of Yazoo City.
178.56	At Forlorn, 50 feet west of center line Yazoo & Mississippi Valley Railroad and 40 feet north of railroad water tank.
157.31	At Cox Ferry, 12 feet north and 6 feet west of northeast corner of Cox's house, in front yard between two west posts of bell tower.

APPENDIX II.

FLOODWAY DATA.

Computation of capacity of river floodway.

Station.		Drain- age area.	Re- quired capac- ity.	Dis- tance, center to cen- ter of levees.	Floodway, exclusive of river channel.				River channel.			Total capac- ity.	Remarks.	
From—	To—				Area of cross section.	Slope.	Depth of flow.	Veloc- ity.	Capac- ity.	Area of cross section.	Slope.			Veloc- ity.
		<i>Sq. mi.</i>	<i>Sec.-ft.</i>	<i>Fect.</i>	<i>Sq. ft.</i>	<i>Ft. per mi.</i>	<i>Fect.</i>	<i>Ft. per sec.</i>	<i>Sec.-ft.</i>	<i>Sq. ft.</i>	<i>Ft. per mi.</i>	<i>Ft. per sec.</i>	<i>Sec.-ft.</i>	
1 60	257	165	12,900	1,150	5,580	2.11	5.0	2.24	12,500	400	1.65	2.49	13,495	Station 257, end of ditch No. 4
257	342	282	17,500	1,500	7,340	1.85	5.2	2.17	15,950	465	1.19	2.20	16,975	Station 342, mouth of Calabretta Creek.
342	381	346	13,300	1,500	8,075	1.85	5.5	2.26	18,250	465	1.19	2.20	19,275	Station 381, mouth of McCurtens Creek.
381	444	387	20,900	1,500	8,210	2.11	5.6	2.44	20,030	645	1.19	3.01	21,970	
444	841	404	21,200	1,500	8,210	2.11	5.6	2.44	20,030	645	1.19	3.01	21,970	
841	892	485	22,940	1,500	8,210	2.11	5.6	2.44	20,030	645	1.19	3.01	22,620	
892	992	485	22,940	1,570	8,620	1.95	5.75	2.32	20,000	1,040	1.06	2.89	23,000	Station 992, mouth of Mulberry Creek.
992	1109	536	24,980	1,500	8,620	1.95	6.05	2.32	21,050	1,040	1.06	2.89	23,300	Station 1109, mouth of Poplar Creek.
1109	1309	627	26,950	1,500	9,020	2.11	6.2	2.58	23,300	1,395	1.06	2.96	27,430	Station 1309, mouth of Lewis Creek.
1309	1494	685	27,750	1,600	9,750	2.11	6.25	2.68	25,900	1,525	1.06	3.02	30,510	Station 1494, mouth of Dry Creek.
1494	1586	701	28,040	1,600	9,750	1.69	6.25	2.38	23,100	1,525	1.06	3.02	27,710	
1586	1636	701	28,040	1,800	11,000	1.43	6.4	2.18	24,050	1,525	1.06	3.02	28,660	Station 1636, mouth of Hays Creek.
1636	1853	795	30,200	1,700	10,800	1.69	6.5	2.42	26,200	1,525	1.06	3.02	31,340	Station 1853, mouth of Peachhollow Creek.
1853	1906	842	31,150	1,800	11,450	1.69	6.5	2.42	27,080	1,270	1.06	2.89	30,760	
1906	1956	842	31,150	1,900	12,100	1.69	6.6	2.23	27,100	1,270	1.06	2.89	33,560	Station 1956, mouth of Zippha Creek.
1956	2226	950	33,250	1,800	11,870	1.69	6.75	2.51	29,900	1,270	1.06	2.89	36,300	Station 2226, mouth of Martin Creek.
2226	2348	987	34,000	1,800	11,870	1.69	6.75	2.51	29,900	1,540	.92	3.16	34,770	Station 2348, mouth of Jordan Creek.
2348	2491	1,010	34,600	1,800	11,870	1.69	6.75	2.51	29,900	1,540	.92	3.16	34,770	Station 2491, mouth of Apookta Creek.
2491	2654	1,117	36,800	1,800	12,345	1.90	7.0	2.71	33,500	1,540	.92	3.16	38,370	Station 2654, mouth of Indian Creek.
2654	2816	1,127	37,200	1,800	12,345	1.90	7.0	2.71	33,500	1,525	1.06	3.34	38,590	
2816	2955	1,145	37,600	1,800	12,345	1.90	7.0	2.71	33,500	1,770	1.06	3.38	39,450	Station 2955, mouth of Long Creek.
2955	3184	1,225	39,300	1,800	12,345	1.90	7.0	2.71	33,500	2,120	1.06	3.35	40,600	Station 3184, mouth of Box Creek.
3184	3290	1,274	39,900	1,800	12,345	1.90	7.0	2.71	33,500	2,120	1.06	3.35	40,900	
3290	3331	1,274	39,900	1,800	12,345	1.58	7.1	2.5	34,400	.....	.....	.....	42,600	Station 3331, mouth of Senatcha Creek.
3331	3768	1,357	43,250	1,800	12,780	1.90	7.25	2.78	35,600	.....	.....	.....	43,490	Station 3768, mouth of Bear Creek.
3768	4017	1,450	43,250	1,800	12,780	1.95	7.25	2.82	36,100	2,135	1.06	3.46	46,900	Station 4017, mouth of Cypress Creek.
4017	4159	1,592	45,800	1,900	13,510	1.95	7.25	2.82	38,200	.....	.....	.....	49,600	
4159	4209	1,592	45,800	2,100	14,975	1.95	7.4	2.63	39,400	.....	.....	.....	51,000	Station 4209, mouth of Doaks Creek.
4209	4472	1,804	49,800	2,000	14,730	1.95	7.5	2.89	42,600	.....	.....	.....	53,250	Station 4472, mouth of Bear Creek.
4472	4572	1,804	49,800	2,200	16,220	1.95	7.8	2.71	44,000	1,815	.92	3.22	54,575	Station 4572, mouth of Panther Creek.
4572	4601	1,971	52,800	2,000	15,690	1.95	8.0	3.02	47,000	1,765	.92	3.16	54,575	Station 4601, mouth of Deer Creek.
4601	4651	2,023	53,900	2,100	17,290	1.69	8.1	2.81	48,700	1,765	.92	3.16	54,575	
4651	4800	2,023	53,900	2,100	16,995	1.69	8.6	2.83	49,000	1,765	.92	3.16	54,575	

4880	2,267	58,100	2,000	17,025	1.48	9.0	2.88	50,800	2,145	.92	3.2	6,875	57,675	Station 5591, mouth of Bogue Chitto.
5341	2,267	58,100	2,200	19,425	1.21	9.1	2.60	50,500	2,145	.92	3.2	6,875	57,375	
5341	2,400	60,700	2,000	18,110	1.48	9.25	2.95	53,500				27,000	60,500	Station 5835, mouth of Bogue Fela.
5700	2,470	62,000	2,000	19,000	1.32	9.5	2.88	54,700	2,380	.92	3.45	8,200	62,900	Station 5902, mouth of Cox Ferry.
5885	2,470	62,000	2,000	19,000	1.32	9.85	2.88	54,700	2,380			8,200	62,900	

¹ Floodway starts at Station 60 of profile down general course of valley (fig. 11).

² Interpolated with reference to channel cross section.

³ Slope of ground surface, Station 2348 to Station 2491, is 1.90. Water surface is calculated at grade of 1.69, thus gaining 0.25 foot in depth.

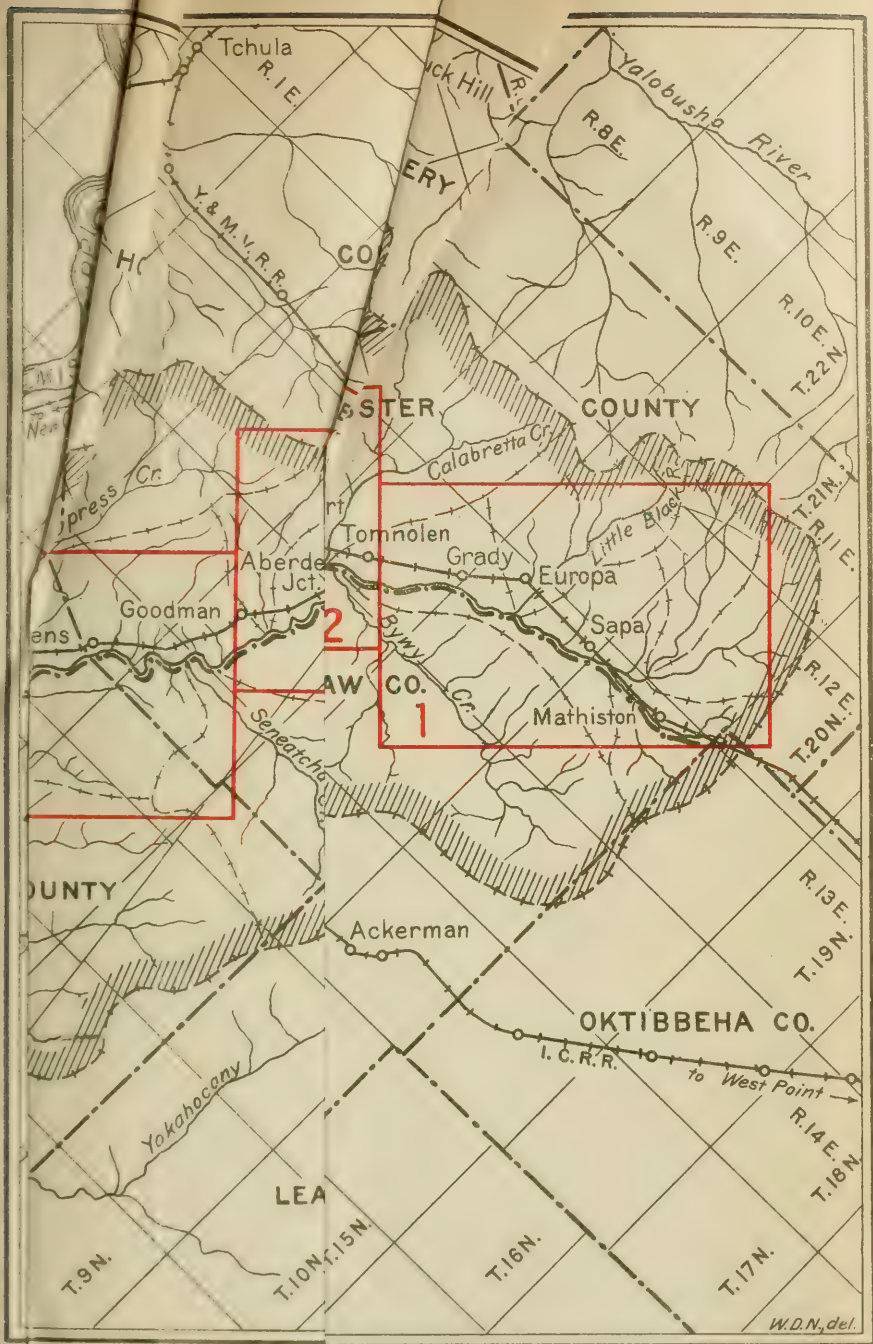
Computation of capacity of creek floodways.

District number.	Name.	Drainage area.	Required capacity.	Distance, center to center of levees.	Slope.	Floodway, exclusive of ditch section.				Ditch section.				Total capacity.
						Area of cross section.	Depth of flow.	Velocity.	Capacity.	Bottom width.	Depth of flow.	Area of cross section.	Velocity.	Capacity.
		Sq. mi.	Sec.-ft.	Feet.	Ft. per mi.	Sq. ft.	Feet.	Ft. per sec.	Sec.-feet.	Feet.	Feet.	Sq. ft.	Ft. per sec.	Sec.-ft.
3	McCurteus Creek, upper end.....	42	3,770	440	2.56	1,266	3.5	1.88	2,380	10	10	190	3.72	2 at 700
7	McCurteus Creek, lower end.....			300			5.6			(¹)	11.5	320	3.94	2 at 1,260
	Poplar Creek, upper end.....	82	3,370	630	2.11	2,390	4.5	2.04	4,860	(¹)				
23-25	Poplar Creek, lower end.....			310			5.9			(¹)	8	375	3.71	2 at 1,390
	Lamps Creek, upper end.....	19	1,710	190	2.11	477	3.0	1.52	730	(¹)				
26-28	Lamps Creek, lower end.....			300			8.0	2.74	2,920	(¹)	16	1,470	5.20	7,650
	Panther Creek, upper end.....	50	4,400	275	1.58	1,064	8.25			(¹)	9.5	550	3.65	2,010
25-27	Panther Creek, lower end.....			300			4.0	1.66	860	(¹)				
	Picket Creek, upper end.....	24	2,120	225	1.58	520	8.0			(¹)	9.5	640	4.66	2,980
27-30	Picket Creek, lower end.....			300			4.0	1.92	1,350	(¹)				
	Cypress Creek, upper end.....	32	2,890	210	2.11	704	9.0			(¹)	12.0	720	5.96	4,290
30-31	Cypress Creek, lower end.....			300			5.0			(¹)				
	Walachi Bogue, upper end.....	32	2,860	260	3.17	745	9.0	2.68	2,000	(¹)				
	Walachi Bogue, lower end.....			300										

¹ Ditch to be of sufficient size to build levees.

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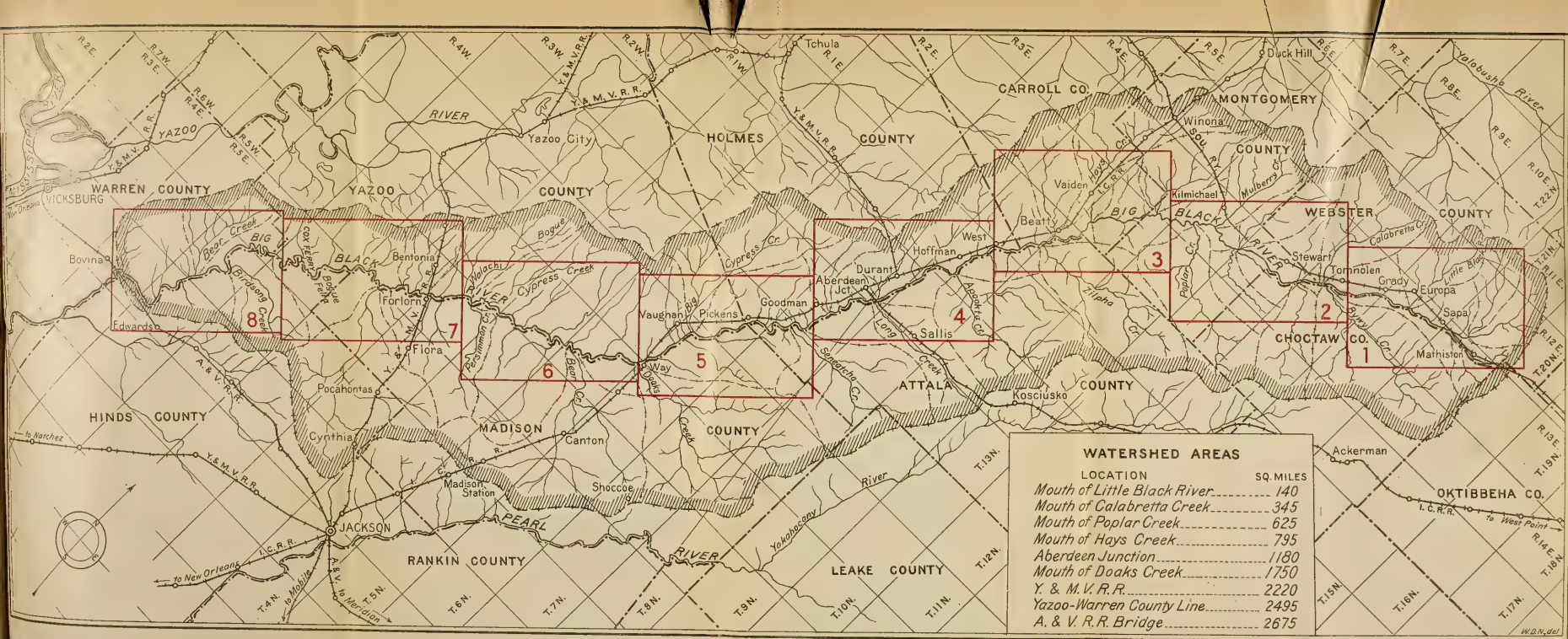
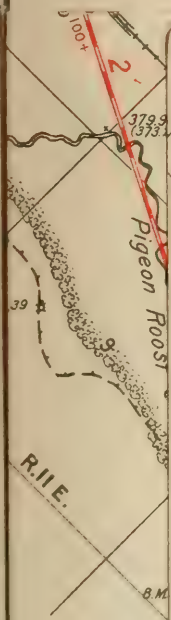


Fig. 2.—Watershed map of Big Black River, Mississippi, and index of map, figure 10

ERIMENT STATIONS



Will D. Nichols, del

Fig. 10
SHEET 1 of 6 Sheets

U.S. DEPT. OF AGRICULTURE, BUREAU OF RECLAMATION

OFFICE OF EXPERIMENT, WASHINGTON

DRAINAGE INVESTIGATIONS

S. H. MCGRORY, CHIEF

BIG BLACK RIVER VALLEY MISSISSIPPI

SHOWING PROPOSED PLAN OF FLOOD CONTROL

Prepared to accompany a Report upon the Reclamation of the
Overflowed Lands along the Big Black River, Mississippi

LEWIS A. JONES, DRAINAGE ENGINEER

Assisted by W. J. SCHLUCK, Drainage Engineer, and
C. E. RAMSEN, Assistant Drainage Engineer

1914

SCALE OF FEET
0 100 200 300 400 500 600 700 800 900 1000



LEGEND

District Numbers	26
Proposed Levees	—
Proposed Flood Gates	—
Proposed Ditches	—
Ditch Numbers	46, 12
Shoal Numbers	—
Proposed Channel Clearing	—
Branch Marks	—
High Water	—
County Line	—
Township Line	—
Section Line	—
Wild Line	—
Timber Line	—
Public Roads	—
Surface Elevations (Walt Bottom)	—
Bottom Elevations	—
Width of Channels	—

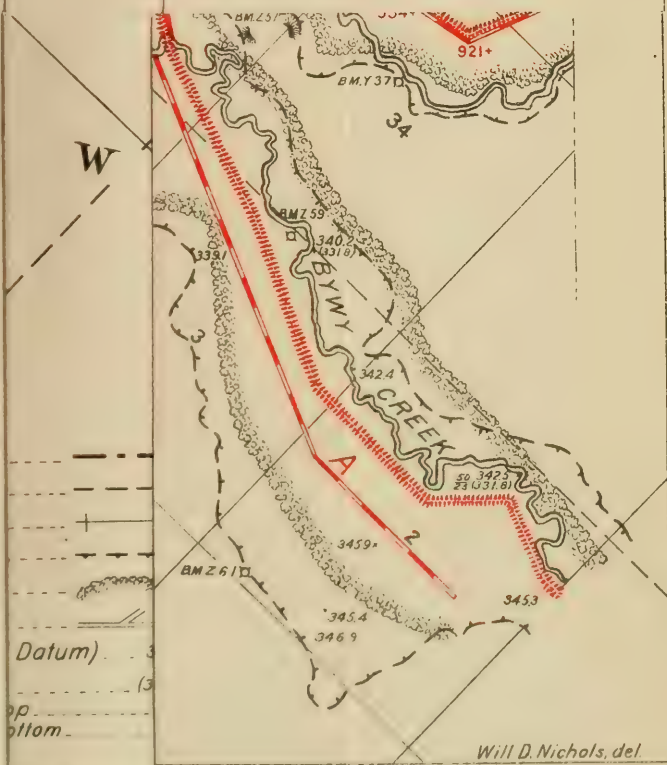


Fig. 10
SHEET 2 of 8 Sheets

U. S. DEPT. OF AGRICULTURE BUREAU

OFFICE OF EXPERIMENTAL STATIONS

DRAINAGE INVESTIGATIONS

S. H. MCGRORY CHIEF

**BIG BLACK RIVER VALLEY
MISSISSIPPI**

SHOWING PROPOSED PLAN OF FLOOD CONTROL

Prepared to accompany a Report upon the Reclamation of the
Overflowed Lands along the Big Black River, Mississippi

LEWIS A. JONES, DRAINAGE ENGINEER
Assisted by W. J. SCHLICK, Drainage Engineer, and
C. E. RAMSEY, Assistant Drainage Engineer

1914

SCALE OF FEET
0 1000 2000 3000 4000 5000

LEGEND
District Numbers 26
Proposed Levees 26
Proposed Flood Gates 26
Proposed Ditches 26
Ditch Numbers ABC, 1, 2
Station Numbers 30 31
Proposed Channel Clearing 26
Bench Marks 26
High Water H.W.

County Line 26
Township Line 26
Section Line 26
Rail Line 26
Timber Line 26
Public Roads 26
Surface Elevations (Gulf Datum) 1000
Bottom Elevations 1000
Width of Channels 26
Barriers 26



Y

Will D. Nichols, del.

Fig. 10
SHEET 3 of 8 Sheets

U.S. DEPT. OF AGRICULTURE, C. L. 112

OFFICE OF EXPERIMENT STATIONS

DRAINAGE INVESTIGATIONS

S. H. MCGRORY, CHIEF

BIG BLACK RIVER VALLEY MISSISSIPPI

SHOWING PROPOSED PLAN OF FLOOD CONTROL

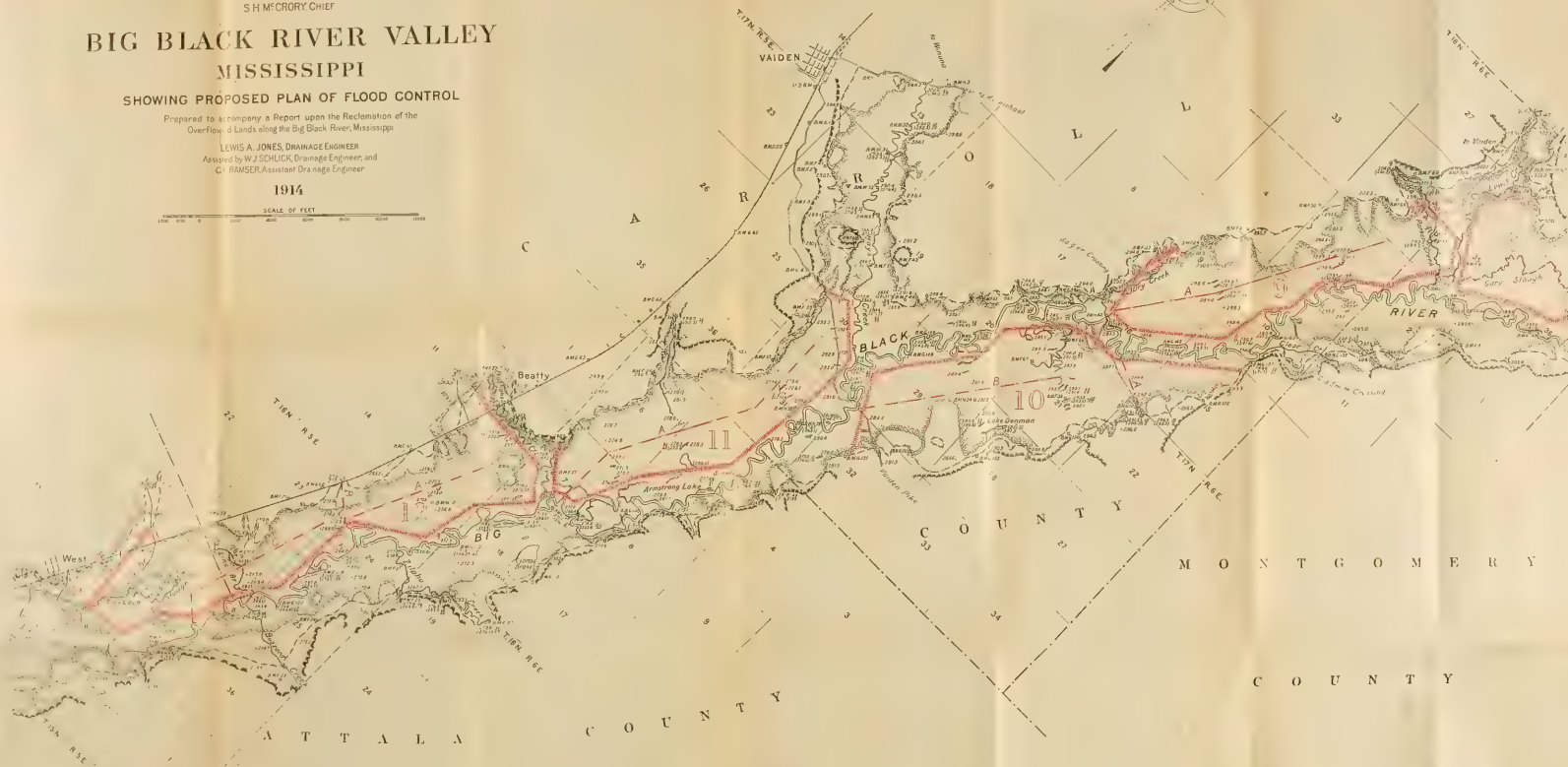
Prepared to accompany a Report upon the Reclamation of the
Overflowed Lands along the Big Black River, Mississippi

LEWIS A. JONES, DRAINAGE ENGINEER

Assigned by W. J. SCHLUCK, Drainage Engineer, and
C. RAMSER, Assistant Drainage Engineer

1914

SCALE OF FEET
1000 800 600 400 200 0



LEGEND

District Numbers.....	26	County Line.....	---
Proposed Levees.....	—	Township Line.....	---
Proposed Flood Gates.....	—	Section Line.....	---
Proposed Ditches.....	—	Mill Line.....	---
Ditch Numbers.....	A, B, C, D, E	Timber Line.....	---
Station Numbers.....	10, 11	Public Roads.....	---
Proposed Channel Clearing.....	—	Surface Elevations (Gulf Datum).....	1000
Bench Marks.....	B. & M. 524	Bottom Elevations.....	1000
High Water.....	H.W.	Width of Channels.....	Bottom

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Di
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W. J. P. A. 1885, 2

Fig. 10
SHEET 4 of 8 Sheets

U.S. DEPT. OF AGR. CULTURE, 1914

OFFICE OF EXPERIMENT STATIONS

DRAINAGE INVESTIGATIONS

S. H. MCGRORY, CHIEF

**BIG BLACK RIVER VALLEY
MISSISSIPPI**

SHOWING PROPOSED PLAN OF FLOOD CONTROL

Prepared to accompany a Report upon the Reclamation of the
Overflowed Lands along the Big Black River, Mississippi

LEWIS A. JONES, DRAINAGE ENGINEER
SCHLICK, Drainage Engineer, and
W. Assistant Drainage Engineer

1914

SCALE OF FEET



LEGEND

District Numbers	County Line
Proposed Levees	Township Line
Proposed Flood Gates	Section Line
Proposed Ditches	Half Line
Ditch Numbers	Timber Line
Section Numbers	Public Roads
Proposed Channel Clearing	Surface Elevations (Gulf Datum)
Beach Marks	Bottom Elevations
High Water	Width of Channels

BIG

SHO

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Fig. 10
SHEET 5 of 8 Sheets

U. S. DEPT. OF AGRICULTURE, BUL. 101 OFFICE OF EXPERIMENT STATIONS

DRAINAGE INVESTIGATIONS

S. H. MCCRODY, CHIEF

BIG BLACK RIVER VALLEY MISSISSIPPI

SHOWING PROPOSED PLAN OF FLOOD CONTROL

Prepared to accompany a Report upon the Reclamation of the
Overflowed Lands along the Big Black River, Mississippi.

LEWIS A. JONES, DRAINAGE ENGINEER
Assisted by W. J. SCHUCK, Drainage Engineer, and
C. E. RAMSER, Assistant Drainage Engineer

1914

SCALE OF FEET
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

LEGEND

District Numbers	21	County Line	---
Proposed Levees	—	Township Line	---
Proposed Flood Gates	—	Section Line	---
Proposed Ditches	—	Mill Line	---
Ditch Numbers	ABC 12	Timber Line	---
Station Numbers	50 55	Public Roads	---
Proposed Channel Clearing	—	Surface Elevations (Gulf Datum)	1000
Bench Marks	1000	Bottom Elevations	1000
High Water	1000	Width of Channels	40
			10

U. S. DEPT. OF AGRICULTURE

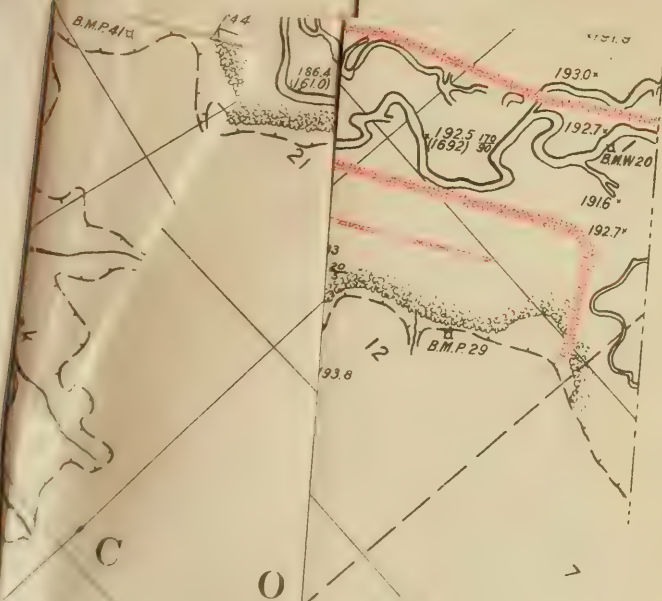


Fig. 10
SHEET 6 of 8 Sheets

U.S. DEPT. OF AGRICULTURE, BUL. 181

OFFICE OF EXPERIMENT STATIONS

DRAINAGE INVESTIGATIONS

S. H. MCCORMY, Chief

BIG BLACK RIVER VALLEY MISSISSIPPI

SHOWING PROPOSED PLAN OF FLOOD CONTROL

Prepared to accompany a Report upon the Reclamation of the
Overflowed Lands along the Big Black River, Mississippi

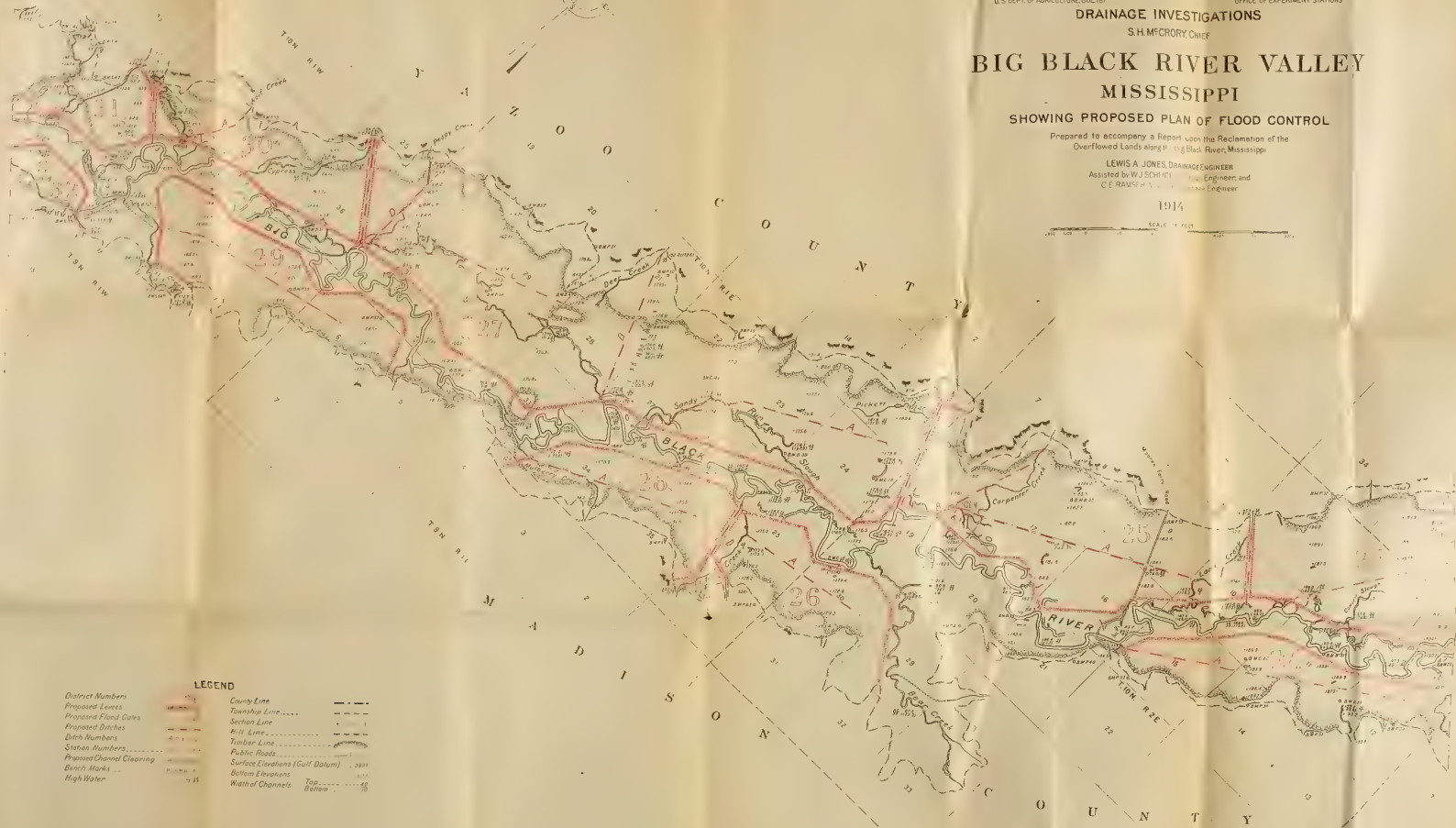
LEWIS A. JONES, DRAINAGE ENGINEER

Assisted by W. J. SCHULTZ, Civil Engineer, and
C. E. RANSFORD, Civil Engineer

1914

SCALE 1" = 1 MILE

LEGEND		
District Numbers	County Line	-----
Proposed Levees	Township Line	.....
Proposed Flood Gates	Section Line	-----
Proposed Ditches	R.R. Line	-----
Ditch Numbers	Timber Line	-----
Station Numbers	Public Roads	-----
Proposed Channel Clearing	Surface Elevations (Gulf Datum)	
Bench Marks	Bottom Elevations	
High Water	Width of Channels	Top ----- Bottom -----



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Will D Nichols, del

Fig. 10
SHEET 7 of 8 Sheets

U. S. DEPT. OF AGRICULTURE, BUL. 181

OFFICE OF EXPERIMENT STATIONS

DRAINAGE INVESTIGATIONS

S. H. MCCRODY, CHIEF

BIG BLACK RIVER VALLEY MISSISSIPPI

SHOWING PROPOSED PLAN OF FLOOD CONTROL

Prepared to accompany a Report upon the Reclamation of the
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LEWIS A. JONES, DRAINAGE ENGINEER
Assisted by W. J. SCHLICK, Drainage Engineer, and
C. E. RAMSER, Assistant Drainage Engineer

1914

SCALE OF FEET



LEGEND

District Numbers.....	25	Camp Line.....	---
Proposed Flood Gates.....	—	Township Line.....	---
Proposed Ditches.....	—	Section Line.....	---
ABC 12.....	—	Hill Line.....	---
Section Numbers.....	—	Timber Line.....	---
Prop. Section Line no.....	—	Public Roads.....	---
Branch Roads.....	—	Surface Elevations (Gull Datum).....	1000
Gr. Water.....	—	Bottom Elevations.....	1000
		Width of Channels.....	Top.....
			Bottom.....

LEY

OL

Will D. Nichols, del.

LEGEND

County Line
 Township Line
 Section Line
 Hill Line
 Timber Line
 Public Roads
 Surface Elevations (Gulf Datum)
 Bottom Elevations
 Bench Marks
 High Water
 Width of Channels
 Bottom
 High Water
 Width of Channels
 Bottom

WARREN COUNTY

COUNTY

HINDS

Fig. 10

SHEET 6 of 6 Sheets

U. S. DEPT. OF AGRICULTURE BUL. 161

OFFICE OF EXPERIMENT STATIONS

DRAINAGE INVESTIGATIONS

S. H. MCCORMY CHIEF

BIG BLACK RIVER VALLEY MISSISSIPPI

SHOWING PROPOSED PLAN OF FLOOD CONTROL

Prepared to accompany a Report upon the Reclamation of the
 Overflowed Lands along the Big Black River, Mississippi.

LEWIS A. JONES, DRAINAGE ENGINEER
 Assisted by W. J. SCHUCK, Drainage Engineer, and
 C. F. RANGLITZ, Assistant Drainage Engineer.

1914

SCALE OF FEET
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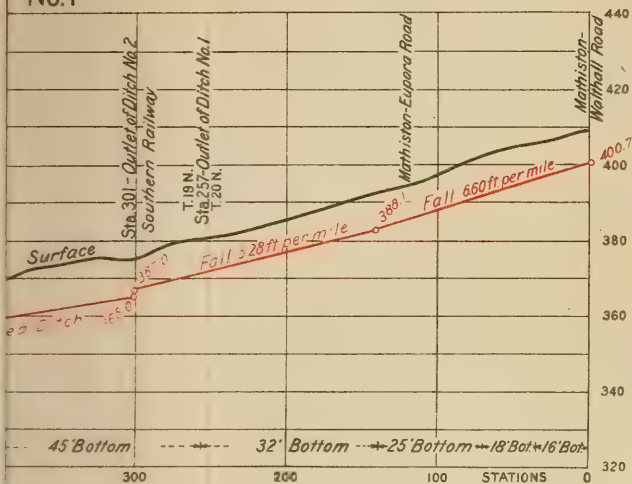


Fig. 11
U.S. DEPT. OF AGRICULTURE
DRAINAGE INVESTIGATIONS
S. H. MCCREARY CHIEF

BIG BLACK RIVER VALLEY MISSISSIPPI

SHOWING PROPOSED PLAN OF FLOOD CONTROL

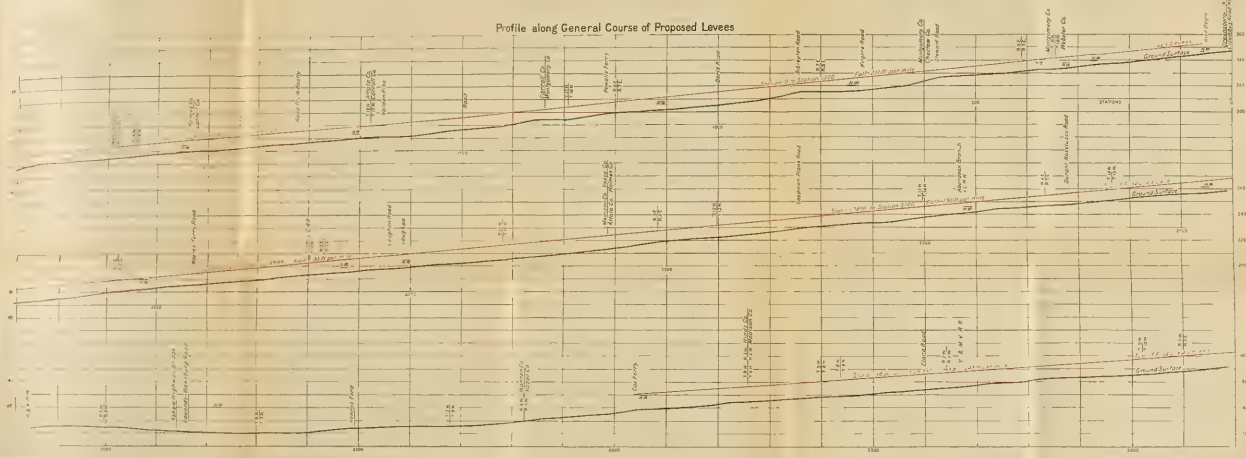
Over-flooded Lands along the Big Black River, Miss. 300

LEWIS A. JONES, DRAINAGE ENGINEER

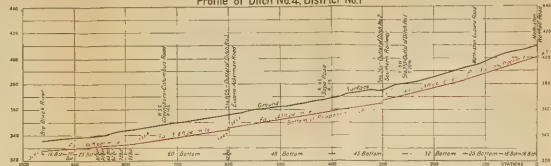
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Distances refer to Gulf Station

Profile along General Course of Proposed Levees



Profile of Ditch No. 4, District No. 1



Mathiston-Eupora
Winhuuu

Station 963—Fall—280 ft. per mile

STATIONS

yon Highway Bridge

10000

3750 to Station—12650—Fall—0.92 ft. per

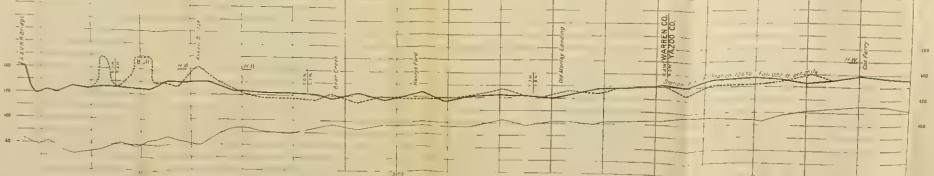
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Front of River Banks and Bottom



EFFECT OF TEMPERATURE ON THE STRENGTH OF POLYMER-BLENDED CONCRETE

S H McCROBY CHIEF

SHOWING PROPOSED PLAN OF FLOOD CONTROL

Prepared to accompany a Report upon the Reclamation of the
Overflowed Lands along the Big Black River, Missouri.

Abbreviations refer to Gulf (page 104)



BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE



No. 182

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
February 2, 1915.

(PROFESSIONAL PAPER.)

AGRICULTURAL ALCOHOL: STUDIES OF ITS MANUFACTURE IN GERMANY.¹

By EDWARD KREMERS,

Special Agent, Plant Physiological and Fermentation Investigations.

REVIEW OF THE PROBLEM OF MANUFACTURE.

INTRODUCTION.

The brandy (Branntwein) which in the fourteenth century was brought over the Alps from Italy to Germany found in the fifteenth century a competitor in a whisky (Kornbranntwein) which was made from cereals. The distilled fermented grape juice (wine) of

¹ Early in the fiscal year 1907-8 the Bureau of Plant Industry began an investigation of the problem of utilizing the waste and surplus products of American farms as a source for the manufacture of denatured alcohol. In view of the vast possibilities of this investigation, involving important questions not only of agricultural but likewise of economic and social import, it was deemed wise first of all to seek guidance from European experience. It seemed especially desirable to study the situation in Germany, where for a considerable period of time industrial alcohol from agricultural sources has been most conspicuously successful. Accordingly, arrangements were made to send Dr. Edward Kremers, of the University of Wisconsin, as special agent to visit those countries of Europe in which agricultural alcohol has been most prominently developed and to study as thoroughly as his stay would permit those factors likely to prove most important to America. As was anticipated, relatively little practical aid was obtained on the agricultural phases of the problem from England, Belgium, Holland, or France, and the greater part of Dr. Kremers' attention was given to the conditions to be observed in Germany.

The preparation for publication of Dr. Kremers' report was undertaken by Dr. Rodney H. True, Physiologist in Charge of the Office of Plant Physiological and Fermentation Investigations, of this bureau.

This report brings out the fact that the success of agricultural alcohol in Germany is the result of long-continued experimentation, backed by a determination on the part of those high in authority that the project should succeed. Private enterprise patriotically combined for this definite purpose rather than for private gain seems to have been a factor hardly less effective. The development of agricultural alcohol is found to be based on the principles of operation characteristic of manufacturing enterprises, and it bears little resemblance to the small farm enterprise to which many in this country have looked forward. Alcohol is seen to be not a separable source of income to the German landowner but a necessary factor in a large agricultural operation, the profits appearing rather in enhanced land values, larger yields of grain and forage crops, and in the dairy products made possible by the crops produced.

It is perhaps not to be expected that America can proceed along the same lines as Germany, but in our attempt to solve this problem of crops to afford light, heat, and power there is much of value in the German experience. WM. A. TAYLOR, *Chief of Bureau.*

the Mediterranean countries was replaced by the distillate of a fermented infusion (beer) from cereals of the more northern States. The consumption of the whisky became so widespread that restrictive measures had to be adopted by governments, not only for ethical and social reasons (Gildemeister and Hoffmann, 1899, p. 34),¹ but for economic reasons as well, it being feared that in years of poor harvests too large a quantity of the cereals might be withdrawn from their more legitimate use in bread making (Brockhaus, 1894, p. 501).

The first potato distillery was operated in Monsheim in the Palatinate as early as 1750, but the alcohol industry in Germany up to 1840 was based almost exclusively upon the use of cereals as crude material. The industry has developed primarily in the cities on a small scale (Kleingewerbe), and even as a side issue to other industries (Nebengewerbe). However, with the expansion of the cultivation of the potato—which gives a larger yield of starch per acre than the cereals—the distillation of alcohol became largely an agricultural industry. The western provinces of Germany with their more clayey soils were favorable to the cultivation of the sugar beet, whereas the light sandy soils of the eastern provinces (Brandenburg, Posen, and Silesia) were especially benefited by the cultivation of the potato. For this reason the distilleries in the western part are to-day primarily grain distilleries and are located at or near the cities. In south Germany (Baden, Wurttemberg, and Alsace-Lorraine) apples and other fruits, according to quantity of the crops obtained, are utilized in the distillation of alcoholic beverages. As in France, this industry, which is scarcely deserving of the name, is a home industry and is conducted on only a very small scale.

The agricultural significance of the development of the potato-alcohol industry as worked out in Germany is manifold:

(1) All of the ingredients taken from the soil by the potatoes are returned to the soil.

(2) The spent mash (Schlempe), which is the product obtained after the starch has been converted into alcohol and the latter has been removed by distillation, is a valuable feed for cattle. This enables the farmer to maintain a larger number of cattle than would otherwise be possible, and they in turn provide the manure so necessary for the light soil.

(3) The introduction of a cultivated crop (Hackfrucht) into the rotation has been of the greatest benefit, because it has made possible larger yields of grain even where the area devoted to cereal cultivation had to be reduced for the sake of the potato.

(4) Last, but not least, it has enabled the farmer to convert the unstable potato crop, especially of those varieties having poor keeping qualities, into a stable product, alcohol, which may be held as surplus stock for several years.

¹ For citations to the literature, see the list at the end of this bulletin.

THE ECONOMIC SITUATION.

It would appear that as soon as the production of alcohol became an industry it was placed under governmental control. Not only for ethical reasons was this necessary, but for economic reasons as well. The fact that although alcohol as a beverage is not a physiological necessity, but that nevertheless there is a strong demand for it by man, makes it an especially opportune object for raising internal revenue. Under such conditions it is self-evident that the development of the alcohol industry in any country will be materially influenced by revenue and other legislation.

While the increased tax on alcohol used as a beverage placed a national check upon its consumption and therefore upon its manufacture, the rapid strides which have been made, especially in the improvement of the crude material, are directly attributed to the operation of a certain phase of the laws taxing the finished product.

MASH-CAPACITY TAXES, 1820 AND 1868.

The tax which up to 1820 was levied upon the still was in that year replaced in Prussia and in others of the North German States by a mash-capacity tax. To control the output of alcohol and to tax this directly was not considered feasible, although theoretically it was the simplest and most equitable method. Inasmuch as the ratio between the volume of mash, as made in those days, and the finished product was fairly well established, the taxation of the mash capacity, while indirect, appeared more equitable and fair than a tax on the distilling apparatus, a much more variable factor in the process of manufacture.

The average yield of alcohol about 1820 was computed at 2.5 per cent of the mash, a very low figure when compared with the results attained since then. Immediately, therefore, it became an object to the manufacturer to crowd as much fermentable material as possible into each unit of his mash-tub capacity. This was accomplished on the one hand by thickening the mash and on the other hand by choosing those potatoes which were richest in starch. As will be seen later, this second factor led to the general cultivation of potatoes richer in starch; and, since it was much to his advantage to secure the most complete fermentation possible, the distiller was led to a more careful study and manipulation of the yeast.

The inevitable result was that the original tax on the basis of a 2.5 per cent alcohol yield became antiquated and had to be increased gradually in accordance with the improvements made in the technology of fermentation. With each increase in the rate of taxation

a further incentive was given the manufacturer to improve the process as well as the material.

In 1868 the law regulating the mash-capacity tax, which had applied to Prussia and only a part of the other North German States, was extended to all of the States of the North German Federation.

From the following figures the development of the alcohol industry under this mode of taxation is readily shown. Previous to 1857, the year in which the Association of Spirit Manufacturers of Germany (Verein der Spiritus Fabrikanten in Deutschland) was organized, but few data are available. The low yield of 2.5 per cent, on which the rate of taxation was based in 1820, speaks for itself. In 1853, 5,962 distilleries were operated in Prussia (Meitzen, 1869, p. 553). Of these, 4,701 were located in the country and 1,261 in the cities. Within the same territory in 1907 there was but little deviation, the number of distilleries being 5,995 (Behrend, 1907, p. 395). However, the growth of the distilling industry can not be measured by the number of plants. For example, a reduction of the number of small stills in Bavaria and their replacement by larger, more rational outfits meant a positive advancement. A more correct indicator of the growth is found in the quantities of crude material used. For Prussia in 1855 and for the corresponding territory in 1905, the figures, expressed in pounds avoirdupois, are shown in Table I.

TABLE I.—*Potatoes and grain used for distillation in Prussia.*

Material used.	1855	1905
Potatoes.....pounds..	1,915,800,000	4,706,820,000
Grain.....do.....	308,640,000	518,080,000

The consumption of potatoes, therefore, has increased $2\frac{1}{2}$ fold during the past 50 years, and that of grain $1\frac{1}{2}$ fold. In this connection it should also be remembered that the starch content of the potatoes has been increased.

The best indication of the growth, however, is found in the output of the finished product. Assuming an alcohol yield of 8 per cent in 1855—a rather high figure—Behrend (1907, p. 395) computes an output corresponding to 32,757,700 gallons (124,000,000 liters) of absolute alcohol. Figured on the same basis, the production in 1860 may be estimated at 42,003,825 gallons (159,000,000 liters) and in 1865 at 52,570,825 gallons (199,000,000 liters) of absolute alcohol. In 1907 the production of spirit in the German Empire exceeded 105,670,000 gallons (400,000,000 liters), and in the territory corresponding to the Prussia of the earlier days it exceeded 79,252,500 gallons (300,000,000 liters). The production of spirit since 1855,

therefore, has increased fully $2\frac{1}{2}$ fold. If it be remembered that the percentage of yield assumed for 1855 was taken rather higher than was in all probability obtained on the average, this ratio becomes favorable.

TAXES ON THE FINISHED PRODUCTS, 1887.

While the tax on the mash capacity, therefore, had had a very beneficial effect on the technology of alcohol and on the industry as a whole, the legislation of 1887 had, at least at first, a very different effect. In addition to the mash-capacity tax, a tax was levied on the finished product when disposed of (*Verbrauchsabgabe*). This second tax was higher than the first and was graded according to the quantity of whisky produced. A certain amount (*Kontingent*), supposed to equal the consumption for beverage purposes established on the basis of the statistics of the previous period of 5 years, was taxed at the rate of 50 cents per gallon. The surplus alcohol above this estimated amount (*Ueberkontingent*) was taxed at the rate of 70 cents per gallon. The alcohol used for industrial purposes was not affected by this legislation, since the tax paid was refunded, as will be shown later.

The considerably increased price for whisky resulted in a corresponding diminution in the consumption. The amount consumed shortly before this law went into effect has been estimated at 79,252,500 gallons (300,000,000 liters) (*Wittelshöfer and Behrend*, 1906, p. 363), whereas in 1887 it dropped to 57,325,975 gallons (217,000,000 liters), that is, about one-third. In the long run it did not pay to produce more alcohol than the demand called for. A considerable reduction in the quantity of alcohol produced had to be the inevitable result. Such a setback to a most important agricultural industry was equivalent to a setback of agriculture at large. In this setback the South German States (Bavaria, Württemberg, and Baden) did not share to the same extent as the North German States, since this law applied only to the northern group. In order to persuade the southern States to accept the same taxation and to join the whisky-tax union (*Branntweinsteuergemeinschaft*), thereby making it effective for the entire German Empire, these States were given a more liberal assignment at the lower tax rate. As a result, the distilleries of these States produced but very little surplus alcohol; that is, practically all of their alcohol was taxed at the rate of 50 cents per gallon (50 marks per hectoliter) and but very little at 70 cents per gallon (70 marks per hectoliter).

The setback which was the immediate effect of the law of 1887 was, in part at least, counterbalanced by other effects which were the indirect outcome of the legislation. While the German distilling industry possibly never faced the problem of prohibition, the legis-

lation of 1887 clearly taught the lesson that the future growth of the consumption of distilled alcohol as a beverage would not be permitted to keep pace with the actual growth in population. Other outlets for the use of alcohol had to be sought, for the industry was greatly in need of expansion.

TAX REFUNDS ON INDUSTRIAL ALCOHOL, 1879 AND 1887.

The law of 1879 had already empowered the Council of the Representatives of the German States (Bundesrath) to grant the same refund of taxes on industrial alcohol that was granted to exported spirits. The first statistical data concerning the consumption of alcohol for industrial purposes date from this period. During the fiscal year 1880-81, 2,462,111 gallons (9,320,000 liters) were thus consumed. This quantity increased until in 1886-87 it amounted to 4,837,044 gallons (18,310,000 liters); that is, it had almost doubled in six years. Yet this amount is insignificant when compared with the drop in consumption of 21,134,000 gallons (80,000,000 liters), due to the tax levied on the finished product when disposed of (Abgabesteuer).

While the law of 1887 had introduced the heavy tax on the finished product, it also brought absolute relief from taxation of all alcohol for purposes other than as a beverage within the boundaries of Germany. The inconveniences which hampered the free use of the tax-free alcohol granted in principle by the law of 1879 were removed, and the completely denatured alcohol became as free as any other commercial commodity after 1887. Though the price of alcohol consumed for beverage purposes was greatly increased through the laws of 1887, the price of that used for technical purposes was lowered.

The results are best expressed in figures. As already stated, the quantity of technical or industrial alcohol used in 1886-87 in the States which were included within the whisky-tax union as constituted before 1887, was 4,834,402 gallons (18,300,000 liters). The quantity thus used immediately jumped to 8,215,842 gallons (31,100,000 liters) for this territory, and to 10,223,572 gallons (38,700,000 liters) for the entire German Empire.

INCREASE IN TECHNICAL APPLICATIONS OF ALCOHOL.

After 1887 there was a constant increase in the consumption of alcohol for technical purposes. However, an increase in consumption which would correspond to the demand for expansion was attainable only when this alcohol could be produced at a sufficiently low price. It was soon recognized that the most important field in which this consumption could be looked for was in its application to the production of heat, light, and power. Its use for the

production of heat was an old field in the application of alcohol. Alcohol burners and alcohol cooking apparatus had been used for a very long time. Its application for illuminating purposes and for generating power were, however, new. The courses to be pursued were indicated on the one hand by the invention of the incandescent mantle by Auer von Welsbach, in consequence of which such rapid strides were made in gas illumination, and, on the other hand, by the invention of the internal-combustion motor. However, in order to accomplish anything of real importance, the price of alcohol had to be reduced to such a point that it could compete with petroleum, the most widely distributed substance used for a like purpose.

DISTILLATION TAX OF 1895, AND BONUS ON INDUSTRIAL ALCOHOL.

The mere freedom from taxation did not suffice for the purpose desired. Other means had to be sought to attain this end. In consequence, there resulted the idea of the distillation tax (*Brennsteuer*), which was incorporated in the law of July 16, 1895. The distillation tax is a progressive tax on production, levied on the products of the distilleries. The revenues from this source are utilized for paying the refund (*Rückvergütung*); that is, a sort of premium or bonus paid on alcohol used within the German boundaries for other than beverage purposes. In other words, the money necessary for this cheapening of industrial alcohol was raised within the distilling industry itself. The effect of this distillation tax became apparent at once. Whereas the alcohol used for industrial purposes in 1894-95 amounted to 18,967,765 gallons (71,800,000 liters), in 1895-96 it amounted to 21,345,000 gallons (80,800,000 liters).

INCREASE IN POTATO CULTURE.

During the decade after the enactment of the law of 1887 the production of alcohol remained fairly constant. With one exception it varied little from 73,969,000 gallons (280,000,000 liters) a year. The exception occurred during the industrial year 1895-96, when the production rose to more than 79,252,500 gallons (300,000,000 liters). From the year 1897-98, however, the production of alcohol in Germany made enormous strides. As a result of the progress made in the cultivation of potatoes, harvests increased to an extraordinary degree. Those yields which formerly were regarded as enormously high were looked upon as barely average. From 1896 the potato crops increased annually until in 1901 they culminated in a harvest of 107,341,970,000 pounds (17,890,329,000 bushels), a yield that was attained a second time in 1905.

That this development should prove of consequence to the distilling industry was inevitable. The excess of potatoes naturally was

forced into the distilleries, thereby increasing the production of alcohol. This was made the more possible because the improved methods of cultivation were yielding potatoes richer in starch and the improvements in technology were causing a large yield of alcohol.

In 1897-98, 79,252,500 gallons (300,000,000 liters) of alcohol were produced, while in 1901-2 not less than 112,010,200 gallons (424,000,000 liters) were manufactured. Owing to the decrease in the potato harvests during the next few years, the production of alcohol dropped somewhat, but it reached its zenith in 1905-6 with a production of 115,444,475 gallons (437,000,000 liters).

For several years after the enactment of the law of 1887, the pecuniary success of the alcohol distilleries was not great. The price per gallon had dropped about 10 cents as compared with the prices obtained before 1887. The "Kontingent" did not afford a sufficient substitute for this reduction in price, since the large majority of distillers, at least in North Germany, were compelled to produce a considerable quantity of alcohol paying the higher tax rate of the "Ueberkontingent." To this must be added the fact that the distillers did not realize the actual average price for the year, but one considerably below the average. The prices of alcohol were fixed by the Chamber of Commerce of Berlin and were so regulated that they were relatively low during those months in which the alcohol was in the hands of the distiller, but they were raised as soon as the producers had disposed of their products. The result, therefore, was that the dealers and not the producers enjoyed the greatest pecuniary benefits from the manufacture of alcohol.

COOPERATION IN MARKETING.

It was soon recognized that relief would result only from a cooperative disposal of the alcohol produced. The basis for a cooperative union had been laid with the establishment and assignment of alcohol production under the lower rate of taxation (*Kontingentirung*). While attempts in this direction were made at once, they did not result in the desired success. In spite of the greatest efforts, a complete union of the entire industry did not immediately result. A number of provincial sale associations (*Verkaufsgenossenschaften*), cooperative organizations for the sale of alcohol, were organized, some of which still exist and constitute, as it were, the centers of crystallization about which the present large organization has developed for the disposal of the alcohol produced in Germany.

It was only with the third attempt, at a time when the position of the alcohol market had become untenable, not only for the agricultural distilleries (*Brenner*), but also for the distilleries and rectifiers in the cities (*Spiritusfabrikanten*), that these efforts were crowned with striking success.

ORGANIZATION OF THE CENTRAL ASSOCIATION.

In 1899 there was organized the Society of German Distillers for the Disposal of Alcohol (*Verwertungsband deutscher Spiritusfabrikanten*), which included not only practically all of the agricultural distilleries, but the most important of the city distilleries and refiners as well. The members of this new organization entered upon a preliminary contract for nine years with the Central Association for the Disposal of Alcohol (*Zentrale für Spiritusverwerthung*), which also was a new corporation, with limited liabilities, to which belonged almost all the rectifiers of alcohol. The members of the Distillers' Society (*Verwertungsverband*) pledged themselves to turn over to the Central Association for the purpose of disposal all of the alcohol manufactured by them. The Central Association in turn promised to dispose of the alcohol in the best manner possible, for a certain compensation which the members received primarily for the rectification of the alcohol thus obtained. The essential feature of the new cooperative organization was that the cooperating agricultural distillers would receive the full year's value for their product and that fluctuations in the price would no longer result exclusively to the benefit of the dealers.

On September 15, 1899, the new cooperative arrangement went into force. A limitation of the production of alcohol by contract was not contemplated. The peculiar nature of the agricultural distillation industry (*Brennereigewerbe*) did not lend itself readily to such a limitation. Besides, the position of those distillers who remained outside of the arrangement would have been strengthened, since these distillers would not have been subject to such a limitation. It therefore became apparent from the very beginning that the Society of Distillers would soon have to face the disposal of large quantities of alcohol, and that this disposal could not be sought in an increase of the amount of spirit used for drinking purposes.

The future of the distilling industry, therefore, lay first of all in the increased use of alcohol for technical purposes, and especially for those purposes to which petroleum was applied. The Central Association from the very beginning of its organization regarded the increase in this demand as its prime object. A special department, the technical section of the Central Association (*technische Abteilung der Zentrale für Spiritusverwerthung*), was created, having manifold duties. It was to test existing apparatus which had been constructed for developing heat, light, and power from alcohol; to establish stores in which such apparatus might be offered for sale to the public; to start a literary campaign for the application of alcohol to household needs; to send outfits to exhibitions; and to organize a retail trade in denatured alcohol, thus assuring the public that the

alcohol was of the required strength and that it could be had at a stable price.

Much has been accomplished in this way, and they do not assume too much who claim that what has been attained is due in the first instance to the Central Association and its technical division. But this activity, important and fruitful of results as it has been, could not have proved satisfactory without such a reduction in the price of alcohol as would allow it to compete with petroleum. Its sale at a price equal to that obtained for beverage alcohol was, therefore, not expedient; and a differentiation in the disposal of the product, according to the use to be made of it, had to be established. Inasmuch as it could not be assumed that any individual would dispose of his products except at the highest price attainable, such a differentiation could be accomplished only by an organization which, like the existing dealers' trust (*Verwertungsunternehmen*), could control the sale of the bulk of the alcohol produced. A large organization which exercises such control can do this, because the loss resulting from the sale of industrial alcohol at a lower price can be made up by the higher price at which alcohol consumed as a beverage is disposed of. Yet it was because of this differentiation in price between alcohol sold for technical purposes and alcohol used for beverage purposes that those who remained outside the Distillers' Society (*Verband*) enjoyed certain advantages. For example, they did not have to contribute to the sacrifices made on behalf of the alcohol consumed for industrial purposes. That such a situation should become a source of unpleasantness was but natural.

SUCCESS OF THE CENTRAL ASSOCIATION.

The striking success with which the activity of the Central Association has been crowned becomes apparent from a few statistical data. In 1898-99, the year in which the Central Association was organized, the consumption of alcohol for technical purposes amounted to 23,511,575 gallons (89,000,000 liters). During the first year of the existence of the association it rose to 26,153,325 gallons (99,000,000 liters), and by 1905-6 it had risen to 39,097,900 gallons (148,000,000 liters). The increase, no doubt, would have been much greater had it not been for the fact that the association had to pass through two crises: (1) In 1901-2, when the development of the technical consumption had to overcome the serious obstacle of the removal of the distillation tax, and (2) in 1904-5 when, in consequence of the failure of the potato crop, the retail price for denatured alcohol had to be increased. Nevertheless, in spite of the increased use of industrial alcohol, it became exceedingly difficult to establish an equilibrium between production and consumption

because of the enormously increased potato production. Indeed, the surplus of alcohol carried over increased from year to year.

VOLUNTARY REGULATION OF PRODUCTION.

In October, 1902, the surplus for which no use could be found amounted to 26,417,500 gallons (100,000,000 liters), approximately double the quantity that had to be carried over in any previous year. Something had to be done to diminish this surplus if a crisis which would affect the entire distilling industry was to be prevented. The consumption could not be sufficiently increased to reestablish the equilibrium, especially since the amount used as a beverage decreased rather than increased. Another measure, therefore, had to be resorted to, namely, the regulation of production. The agreement between the agricultural distiller and the association did not permit of such a regulation by contract. An appeal, however, to the agricultural distillers was not made in vain. The large majority of distillers realized that it would be more profitable for them to produce smaller quantities with reasonable profits than to distill large quantities at a loss. The representatives of 90 per cent of the agricultural potato industry voluntarily agreed to inflict upon themselves a reduction of 18 per cent, calculated on an average production for the years 1896-97 to 1900-1901. The result was that the surplus carried over the next fiscal year dropped to about 7,925,250 gallons (30,000,000 liters). The production agreement henceforth became a standard feature of the distilling industry.

The 9-year contract entered upon in 1899 between the Society of German Distillers and the Central Association expired in 1908, and the renewal of this contract for another nine years was accomplished. While the existing situation was thus assured, the distilling industry nevertheless anticipated the future with some curiosity if not anxiety.

THE POTATO THE PRINCIPAL SOURCE OF ALCOHOL.

The cultivation of the potato in Europe is of quite recent date when compared with that of grain, which has been cultivated two thousand years or more. Toward the end of the sixteenth century, the potato was brought from America to certain parts of Spain and England. At first it was considered a curiosity, and for a long time attracted but little attention when cultivated in gardens. Gradually, however, the value of the potato as a nutritious food became known and its cultivation increased accordingly.

The great extent to which the cultivation of the potato was carried on in Prussia during the second half of the eighteenth century was due to the efforts of Frederick the Great, who appreciated thoroughly the great politico-economical significance of its cultivation.

In importance it no longer competes with the cereals; it exceeds them. Of 64,860,000 acres (26,250,000 hectares) of arable land in the German Empire, 8,150,000 acres (3,300,000 hectares), or 12.5 per cent, were planted with potatoes during the year 1901, a proportion which was maintained essentially unchanged during the five succeeding years. The cultivation of cereals was relatively slight, amounting in 1901 to 3,090,000 acres (1,250,000 hectares), that is, about 4.75 per cent of the total farming area.

Compared with all other civilized countries, Germany has the most extensive potato lands in proportion to both its area and the number of inhabitants. Table II shows the acreage of potatoes cultivated in various countries during the year 1900.

TABLE II.—*Area of potato lands in various countries in 1900.*

Countries.	Calculated on a total area of 100 acres.	Area grown for each 10,000 inhabitants.
	<i>Acres.</i>	<i>Acres.</i>
Germany.....	5.4	158.88
Austria.....	3.9	110.70
Hungary.....	1.8	75.60
France.....	2.9	97.36
Great Britain and Ireland.....	1.6	30.64
Russia.....	.7	81.54
United States.....	.1	34.10

For several years the potato crops of Germany have increased enormously, not only in the quantity produced on a given area, but also in the total amount, as is shown in Table III, covering the years 1896 to 1907, inclusive.

TABLE III.—*Potato crops of Germany for the years 1896 to 1907, inclusive.*

Year.	Area cultivated (acres).	Crop yield (bushels of 60 pounds).		Year.	Area cultivated (acres).	Crop yield (bushels of 60 pounds).	
		Total crop.	Per acre.			Total crop.	Per acre.
1896.....	7,543,444	1,187,875,000	157.5	1902.....	8,008,511	1,595,490,000	199.1
1897.....	7,580,440	1,241,040,000	163.7	1903.....	7,998,627	1,574,930,000	196.8
1898.....	7,612,158	1,349,250,000	177.2	1904.....	8,124,648	1,332,090,000	163.9
1899.....	7,737,845	1,414,100,000	182.7	1905.....	8,196,307	1,773,940,000	216.4
1900.....	7,953,598	1,491,220,000	187.5	1906.....	8,159,242	1,576,220,000	193.05
1901.....	8,200,834	1,788,920,000	218.1	1907.....	8,146,887	1,671,700,000	205.08

Longer periods of time likewise reveal an enormous increase in potato crops, as is shown by the following 5-year averages for a period of 20 years: From 1887 to 1891, 999,780,000 bushels; 1892 to 1896, 1,230,900,000 bushels; 1897 to 1901, 1,460,540,000 bushels; 1902 to 1906, 1,570,530,000 bushels. The increase in the average for the last period over that of the first period amounted to 570,750,000 bushels, or 57 per cent, representing a value in excess of \$90,000,000.

The value of the potato crop in Germany is shown by the following figures, which give the average amount of raw food material produced by the various cereal crops from 1896 to 1901, as compared with potatoes: Rye, 14,726,738,000 pounds; wheat and spelt, 6,790,168,000 pounds; all grains, 21,516,906,000 pounds; potatoes alone, 19,246,158,000 pounds. It becomes apparent, therefore, that potatoes furnished but 10.5 per cent less raw food material than all the cereal products combined.

The potato crops gathered from land which was cultivated according to rational methods exceeded by far the average potato yield. According to statistics collected by the Association of German Distillers for the Disposal of Alcohol, there were harvested in some instances crops of more than 535 bushels per acre, while yields of 300 to 375 bushels per acre were quite common. While it is true that such crops as these were produced only by very intelligent agriculturists and under very favorable conditions, the possibility of attaining these results proves that the total yields will increase considerably in the future, for the experience which the pioneers in this direction have obtained in cultivating potatoes will naturally become common knowledge in the course of time.

Where the cultivation of potatoes is carried on extensively, it forms one of the best supports for rational methods of agriculture, especially where circumstances are unfavorable to the cultivation of the sugar beet. This is the case in the larger part of Germany. While potatoes require good soil and considerable manuring, the care in this direction is rewarded by large crops and an excellent condition of the soil for the next crop, whatever that may be.

The growing of largely increased crops has unfortunately one drawback, namely, the danger of overproduction. Inasmuch as it is not advisable to diminish the area cultivated except in special cases and in a limited manner, it becomes necessary to find outlets for the surplus.

For many years the popular method of utilizing potatoes has been as a crude material in the chemical industries. The most important ingredient, starch, is used either for the manufacture of pure starch or for the transformation into alcohol by means of fermentation after previous saccharification. The process culminates in distillation, in order to separate the alcohol formed from the other substances of the tuber.

In both cases the result is a product of almost unlimited stability, representing a high value in small quantities and providing an article easily convertible into money. The by-products of establishments working with potatoes furnish large quantities of nutritious feed, and therefore potatoes form a valuable crop when, in connection with the agricultural operations, the starch-making and distilling industries are combined.

Distillation is the more important and extensive of these two branches of agricultural industry. The manufacture of spirits is the only form of potato utilization concerning which we possess reliable statistics. It appears that with the increased potato production, the use of this product for the manufacture of alcohol has also increased. Behrend (1905, p. 30) estimates that in 1905, calculating on an average total crop of 1,578,530,000 bushels, 5.8 per cent of the crop, or over 90,000,000 bushels, were used in the manufacture of spirits. At first thought this quantity does not seem large, but it gains in importance when we consider to what extent the distillation of potatoes exists as an agricultural industry in the German Empire.

Many such distilleries are situated in the eastern part of Germany, the principal centers being in the Prussian Provinces, Posen, West Prussia, Pomerania, and Brandenburg. In these eastern regions the price of spirits regulates the price of potatoes. The fact that these agriculturists are accustomed to dispose of their surplus potatoes in the western regions, where the demand is greater than the supply, proves how important a factor such distilleries are.

When considered from another point of view the alcohol distillation becomes the more important as a branch of agriculture, since it alone renders a rational method of agriculture possible in those regions which possess a light soil and are situated, as most of them are, at a distance from business centers. Indeed, thousands of agricultural undertakings owe their existence to these distilleries.

About 6,000 agricultural potato distilleries are in operation in the German Empire, 4,000 of which represent one of the chief activities of the respective farms, whereas the remaining 2,000 have a secondary place.

The production of spirits from other substances, such as grain, fruit, and molasses, is insignificant in comparison with that from potatoes. During the year 1905-6, 115,629,397 gallons (437,700,000 liters) of pure alcohol were produced in distilleries of all kinds (Behrend, 1907, p. 401). Of this quantity, 92,947,035 gallons (351,800,000 liters) were produced in agricultural potato distilleries, representing over \$36,000,000 as total receipts. This is calculated on an average value of about 39 cents per gallon, a price slightly lower than that of the Central Association for that year.

The spent mash, valued at 15 cents for a quintal of potatoes (220.26 pounds), must also be considered, since it represents a value of over \$3,750,000. The total value of products derived from agricultural potato distilleries, therefore, amounted in that year to nearly \$40,000,000 in gross receipts.

THE DISTILLERY AS A FACTOR ON THE MARKET.

It is generally admitted, even by ardent advocates of the agricultural distillery as an economic factor, that alcohol from the numerous agricultural distilleries costs relatively much more than the same article manufactured in the larger distilleries. This conclusion is the direct result not only of general observation, but also of careful computations made at the Institution for Fermentation Industries (Institut für Gährungsgewerbe). This is true in a measure of even the larger agricultural distilleries.

Even the casual visitor to the general agricultural distilleries, who knows nothing of technological computations, must be impressed with the correctness of this statement. Most of the estates have not more than a double operation (Betrieb), whereas a working day of 12 hours would admit of a fourfold operation. The efficiency of the plant, therefore, is but one-half what it might be. On an equipment of \$40,545 (170,000 marks), or even of \$19,080 to \$21,465 (\$0,000 to 90,000 marks), this certainly is an important industrial factor. From the purely industrial point of view, therefore, taking into account the interest on the principal involved, the depreciation of the machinery but half utilized, and the cost of labor not fully utilized, the reason becomes apparent for the statement so often made, even by the strongest advocates of the agricultural distillery, that the distillery does not pay. It should be added, however, that whenever alcohol brings a better price, as was the case during the campaign of 1907-8, even this aspect of the situation is regarded as more hopeful.

However, the owners of estates would not maintain these distilleries if they did not pay in some way; new distilleries would not be built if they were regarded as losing investments, and the Government would not be justified in stimulating these institutions if they were not regarded as an economic factor of importance.

While, therefore, the question of the direct industrial value of these agricultural distilleries is a debatable one, the question of their indirect economic value does not seem to be questioned.

The extended cultivation of the potato—extended so largely for the very reason that the quantity produced over and above that needed for culinary and other usual purposes can be converted into alcohol—has made possible the profitable cultivation of large tracts of light, sandy soil in eastern Germany. One of the other principal uses to which this soil is put is that of forestation (pine), but although timber is very valuable in a way, it does not add to the food resources of the country.

Not only has the extended cultivation of the potato made larger tracts of land productive, but the land already under cultivation has been materially improved by the use of potatoes in the proper rotation of crops. Thus, for example, the yield of grain is increased

when potatoes are cultivated every third year. Since the potato demands deep cultivation this crop accomplishes for the eastern provinces what the sugar beet does for the heavier soils of the western provinces. Furthermore, the alcohol distillery makes possible the ready conversion of an unstable product into a stable one. At best, potatoes can be kept only until the warm weather of the next season sets in, whereas alcohol has been kept by the Central Association for several years following an overproduction. Besides, the potatoes can be sorted, as is done, for instance, in the neighborhood of Berlin, and the best can be put upon the market for eating, while the small and otherwise inferior ones—that is, those which are damaged or which reveal poor keeping qualities—can be taken to the distillery. Again, as soon as the potatoes show signs of decay the capacity of the distillery can be increased. Thus a large part of the waste of an important product of the farm can be saved, for even those potatoes which are already partly decayed can be utilized.

The spent mash—by far the most important by-product of the distillery—and the skins and watery wastes (*Abwässer*) are important adjuncts to the food rations of cattle. The cattle in turn furnish fertilizers to the soil, and are thus profitable aside from the pecuniary advantages derived from the milk and the meat. In order to fully appreciate the value placed on the manure, the by-product of the dairy barn, it is necessary to see with what scrupulous care it is preserved as well as with what large expenditure of time and labor the fields are manured.

Thus everything works hand in hand. After having seen all this, one begins to appreciate more fully why such an organization as the Society of Distillers for the Disposal of Alcohol, consisting almost exclusively of agriculturists, should be willing to spend so much money and energy in finding new industrial outlets for alcohol and for improving and popularizing the present outlets. This class are not trying to improve their situation by stimulating the consumption of alcohol as a beverage but by devoting their entire resources to the increased use of technical alcohol, as it is called. In this way they are not only helping themselves, but they are also striving to make their country independent of Russia and of the United States in so far as the use of petroleum is concerned. Besides, the rapidly growing population of Germany demands that every acre of land be cultivated as intensively as possible. It is interesting to note that whereas the agriculturists as a class show considerable foresight in this respect the average owner of an estate has not yet learned to stimulate the consumption of alcohol by using it for technical purposes on his own premises.

For the sake of convenience the agricultural distilleries of Germany may be classified into three groups, as follows:

- (1) The larger distilleries on the domains, estates, and large farms.
- (2) The small outfits on the small farms.
- (3) The larger cooperative distilleries.

According to the Landwirtschaftlicher Kalendar for 1908, Part II, page 22, there were 14,356 agricultural distilleries in Germany during the season of 1905-6 as opposed to 791 nonagricultural distilleries, and 53,050 stills employed principally in the production of brandy; also 28 distilleries producing alcohol from molasses.

Table IV gives a detailed statement of the capacity of these different classes of stills and shows the total output of each class.

TABLE IV.—German distilleries, showing their number, capacity, and output in 1908.

Capacity classification, based on annual produc- tion, computed as abso- lute alcohol (gallons).	Number of distilleries.						Total, all classes.
	Classified according to crude material principally consumed.						
	Potato.		Cereals.		Molasses.	Other sub- stances.	
	Agricul- tural.	Indus- trial.	Agricul- tural.	Indus- trial.			
0 to 13.2	445	3	4,466	6	.....	a 47,478	52,398
13.2 to 26.4	237	3	1,051	9	.....	a 3,068	4,368
26.4 to 52.8	192	3	516	7	.....	a 1,360	2,078
52.8 to 79.2	162	.....	252	5	.....	b 386	805
79.2 to 132	150	1	174	15	.....	c 294	634
132 to 264	167	2	148	41	.....	d 252	610
264 to 660	297	5	299	129	.....	b 131	861
660 to 1,320	404	2	342	114	.....	47	309
1,320 to 1,980	146	.....	214	72	.....	11	443
1,980 to 2,640	77	.....	115	32	.....	6	230
2,640 to 3,960	211	3	114	56	.....	4	418
3,960 to 5,280	236	1	80	40	1	5	363
5,280 to 7,920	381	1	120	49	1	4	556
7,920 to 10,560	256	2	58	38	.....	2	356
10,560 to 13,200	264	2	58	20	.....	1	345
13,200 to 15,840	255	.....	19	11	.....	.....	285
15,840 to 21,120	528	2	44	17	.....	.....	591
21,120 to 26,400	511	.....	22	10	1	1	545
26,400 to 31,680	448	.....	11	9	2	.....	470
31,680 to 36,960	341	.....	10	8	2	.....	361
36,960 to 42,240	252	1	7	4	.....	.....	264
42,240 to 47,520	149	1	4	5	1	.....	160
47,520 to 52,800	115	.....	3	4	3	.....	125
52,800 to 58,080	61	.....	2	4	3	.....	70
58,080 to 63,360	22	.....	1	6	.....	.....	29
63,360 to 68,640	22	.....	6	3	1	.....	32
68,640 to 73,920	14	.....	1	1	1	.....	17
73,920 to 79,200	8	.....	.....	2	3	.....	13
79,200 to 105,600	14	1	.....	13	3	.....	31
105,600 to 132,000	2	.....	1	7	.....	.....	10
132,000 to 158,400	.....	.....	1	5	4	.....	10
158,400 to 184,800	.....	.....	.....	4	1	.....	5
184,800 to 211,200	.....	.....	.....	3	.....	.....	3
211,200 to 237,600	.....	.....	.....	1	1	.....	2
237,600 to 264,000	.....	.....	.....	1	.....	.....	1
264,000 to 290,400	.....	.....	.....	1	.....	.....	1
290,400 to 316,800	.....	.....	.....	3	.....	.....	3
316,800 to 343,200	.....	.....	.....	2	.....	.....	2
343,200 to 369,600	.....	.....	.....	1	.....	.....	1
369,600 to 396,000	.....	.....	.....	.....	.....	.....	.....
396,000 to 422,400	.....	.....	.....	.....	.....	.....	.....
422,400 to 448,800	.....	.....	.....	.....	.....	.....	.....
448,800 to 475,200	.....	.....	.....	.....	.....	.....	.....
475,200 to 501,600	.....	.....	.....	.....	.....	.....	.....
501,600 to 528,000	.....	.....	.....	.....	.....	.....	.....
528,000 to 554,400	.....	.....	.....	.....	.....	.....	.....
554,400 to 580,800	.....	.....	.....	.....	.....	.....	.....
580,800 to 607,200	.....	.....	.....	.....	.....	.....	.....
607,200 to 633,600	.....	.....	.....	.....	.....	.....	.....
633,600 to 660,000	.....	.....	.....	.....	.....	.....	.....
Total number of dis- tilleries.....	6,367	33	8,169	758	28	c 53,050	68,405
Total production, com- puted as absolute alcohol....gallons..	92,675,892	271,228	7,888,503	11,794,040	2,184,780	806,896	115,621,340

a Of these, 8 are industrial distilleries.

b Of these, 1 is an industrial distillery.

c Of these, 6 are industrial distilleries.

d Of these, 3 are industrial distilleries.

e Of these, 35 are industrial distilleries.

DISTILLERIES ON THE LARGER ESTATES AND DOMAINS.

A better understanding of the part which the distillery plays in the economics of the estate can no doubt be obtained from a few examples. For this purpose data bearing on the agricultural situation as a whole are here tabulated for three estates, two located in the sandy soil of the Mark Brandenburg, not far from Berlin, and the other in the Province of Silesia, in close proximity to soil sufficiently heavy for the cultivation of sugar beets.

TABLE V.—*Alcohol production on the larger estates of Germany.*

Item.	Estates.		
	Dahlem.	Dahlewitz.	Neuguth. ¹
Size of estate.....acres.....	875	1,375	² 2,812
Area of potatoes cultivated.....do.....	250	400	³ 312
Average yield of potatoes per acre.....bushels.....	187 to 213	266	267
Total yield.....do.....	{ 46,666 to 53,333	100,000	83,333
Used in distillery.....do.....		33,000	50,000
Mash capacity.....do.....	385,695	581,185	792,525
Operation (Betrieb).....do.....	Twofold.	⁴ Twofold.	Twofold.
"Kontingent".....bushels.....	10,825.892	(?)	12,152.05
Expected to be distilled.....do.....	(?)	(?)	36,984.5
Cattle on the estate:			
Cows.....	210	100	100
Oxen.....	28	40	50
Calves.....	None.	Many.	150

¹ Does not include forest.

² There is an equal acreage of forest land. Of the 2,812 acres, 2,175 acres are under the plow, the balance meadow, lake, and garden.

³ A larger area is cultivated with clover, lupine, and saradella; 60 acres with sugar beets, etc.

⁴ Part of the time this distillery is expected to operate threefold.

⁵ The amount allotted to the distillery in question.

⁶ The "Kontingent" for this distillery had not been decided definitely.

⁷ These two distilleries being located near Berlin, the managers themselves did not know how much would be distilled. Berlin naturally influences the potato market in the neighborhood much more than the market is affected at the more distant estates.

DISTILLERIES ON SMALL FARMS.

The large majority of the stills in Germany are used, as are those in France, for the production of alcoholic beverages from the juice of grapes, apples, prunes, etc., and not for the manufacture of alcohol as such. Practically all of the distilleries enumerated in Table IV under the heading "Other substances" are stills of this class. Their size and capacity can be judged, in large measure at least, by the annual output of beverage computed as absolute alcohol. Of the total 53,050 stills of this class not less than 47,478 have an annual output of only about 13 gallons of absolute alcohol. In other words, they produce 25 gallons of brandy of approximately 50 per cent strength or about 35 gallons of brandy of approximately 33 per cent strength. These distilleries, or more correctly the domestic stills, have nothing to do with the production of alcohol as such, and even where there are small distilleries for such production of alcohol, they are not considered even as a possible factor in the production of alcohol from

waste products on the farm. Such a use of small stills is regarded as financially impracticable even in countries like France and Germany, where the peasants have long since learned to live most economically and do not allow anything to go to waste.

There are, however, a number of small stills in Germany—large when compared with those just mentioned, but small when compared with the smallest distillery regarded as representing the minimum practical efficiency—which utilize potatoes and cereals for the production of alcohol as such and are maintained in large part for the purpose of supplying spent waste as forage for cows.

Several of these distilleries are still found in southern Germany. With the abolition of bondage during the early part of the nineteenth century, many of the peasants became small individual farmers. In parts of Bavaria, for example, the division of the larger tracts, both municipal and private, into diminutive farms resulted in the decimation of cattle because each farmer desired to cultivate as much of his land as possible. The result was that the land, no longer properly fertilized with stable manure, became more or less exhausted. To counteract this tendency, the cultivation of potatoes was stimulated by the installation of the so-called Pistorius distilling apparatus. Of these stills, mounted near the middle of the nineteenth century, some may yet be seen in operation. However, they are rapidly giving way to larger continuous stills and to a more rational mode of operation through cooperative means. In the village of Perlach, near Munich, where about 15 years ago there were 35 of these stills, but 4 were in operation at the beginning of the season 1907-8, and one of these was abandoned in December, 1907, the owner having purchased an interest in the local cooperative distillery.

Not only are these distilleries hampered in their operation because of their small size, but they are not continuous apparatus and hence involve considerable loss of time in charging (which is done with the aid of a bucket instead of a pump) and heating. Moreover, the men who operate these stills, although they may have had years of experience, have not, as a rule, a technical training. Naturally they can not undertake the production of the necessary yeast; hence, this must be obtained from the nearest brewery. This involves not only a loss of time, but it frequently means poor yeast and consequently poor fermentation. Even if the farmer be a man of somewhat greater intelligence than his distiller, he does not compute profit and loss and either he is satisfied to receive a certain amount of food daily for his stock and to receive money at regular intervals for his alcohol, or he listens to the agricultural lectures and abandons individual operation. The latter course, as already indicated, has become so common of late that there now remain but relatively few of these

small agricultural distilleries which actually produce alcohol as such. This should teach the lesson that false hopes should not be engendered in our farmers. Yet even these distilleries are not operated ephemerally, nor are they fed with what might properly be called waste material. They demand a constant supply of crude material and the constant attention of an operator, whose work often begins at 4 o'clock in the morning.

COOPERATIVE DISTILLERIES.

As already stated, the smaller distilleries engaged in the production of alcohol, not alcoholic beverages, are being replaced rapidly by cooperative distilleries. It is instructive to note at the outset one characteristic feature of the plan, namely, that the unit of cooperation is not expressed in shares having a certain money value nor in hundredweights of potatoes to be supplied, but in the amount of spent mash which the shareholder is privileged to call for daily. It is this feature of the cooperative enterprises which, possibly more than any other, clearly indicates where the value of the agricultural distillery lies, viz, in the maintenance of more cattle, which are so essential to the light, gravelly soils. This condition is found at Perlach, in the valley of the Isar, where one of the largest of the cooperative enterprises is located. A somewhat detailed account of this cooperative distillery is given elsewhere. Suffice it here to say that the contrast between a rational enterprise conducted on a scientific and economic basis and an irrational operation conducted by rule-of-thumb methods could not be greater than the contrast between this cooperative plant and the small still in one of the outhouses of a near-by farm. It should also be pointed out that cooperation in such a place as Perlach is made easy by the proximity of the farm buildings to each other, for the farmers of Perlach are for the most part village neighbors, who, while they work their outlying farms individually, follow their social instincts by living very close together.

REPORT OF VISITS TO AGRICULTURAL DISTILLERIES.

It was deemed wise in connection with this investigation to visit personally a number of agricultural distilleries representing the different types of conditions under which the problem of the production of alcohol has been worked out. Several estates were visited and such points of significance were noted as would be permitted by a single visit. It was clearly impossible to make exhaustive studies of these estates, but it is believed that the data obtained will prove of value.

DAHLEM.

The royal estate of Dahlem lies northwest of Berlin, between Steglitz and the Grunewald, a royal forest of more than 18,750 acres

(30,000 Morgen). It is one of the few of the numerous estates belonging to the State which are not rented or leased but are managed by the State itself. The new Botanical Garden has been created from a part of the original domain. The Pharmaceutical Institute and other public buildings have been erected on ground formerly belonging to it. Other parts have been sold to private individuals, so that at the time of the visit there was a colony of about 2,000 persons in Dahlem. Therefore, in view of the certain ultimate extinction of the estate by the ever-growing city of Berlin, it is natural that only such improvements should be made as are necessary.

The old homestead of the family of Wilmersdorf was erected in 1680 and now serves as a dwelling for the superintendent and as a bureau for the clerical force. The person highest in authority is the Wirklicher Geheimrath, an important government officer, who resides in a villa on the estate and who is an officer of one of the ministries.

For the reasons mentioned above this estate was of special interest because it shows what can be done under conditions by no means the most favorable.

At the time of the visit the area of this estate, aside from the large forest, comprised 875 acres (1,400 Morgen). Of this area, 315 acres were under rye cultivation, 252 acres under potatoes, 150.5 acres under oats, 94.5 acres under beets, and 63 acres under clover and other green forage crops.

The rye and oats were sold and the straw used as bedding for the cows, etc. The beets, of which there were several varieties, were used as fodder, especially in the winter, the leaves being fed in the fall. The clover and green forage crops were fed to the cattle.

There were 210 cows in two stables. For field work there were 14 yoke of oxen. There were 46 horses, 26 of which were employed in the fields, 18 were used to draw the milk wagons, and 2 were used for saddle purposes. Pigs, chickens, etc., were raised only for estate purposes.

Because of its proximity to Berlin, the estate was operated primarily as a dairy farm. On an average, 161.7 gallons of milk were obtained daily. Because of the absence of meadow lands no cattle were raised. Fresh cows were purchased, and after nine months or a year (monthly tests as to yield of milk being made) they were sold in a fattened condition to the butcher. In like manner the oxen were bought when young and after three years of service were sold in a fattened condition without loss.

The milk was delivered to retail customers in Berlin, and only in cases of oversupply, as, for example, during the summer months when the customers were away on their vacations and the sale of the

milk was therefore reduced, were the milk, potatoes, etc., sold to intermediaries. The profits, therefore, were not divided with any one except in cases of necessity.

As the production of the cereals serves two purposes, that of providing grain, which finds a good market in Berlin, and straw for bedding the cattle, so the potato also serves two purposes. The good tubers are sold, while the small and defective ones are kept for the distillery and ultimately furnish a by-product which is fed to the cattle.

Several varieties of potatoes are cultivated, with reference to the local market and with reference to their value as crude material for the distillery. Some of the table potatoes brought as high as 55 cents per bushel, others only half that sum. The average for the sorted product of the season of 1907 was about 44.4 cents per bushel. The summer of that year in Germany was cold and cloudy and was not very favorable for the potato crop.

The proximity to Berlin and the possibility of selling the better potatoes directly to the consumer act favorably on the price to be obtained. The smaller and poorer potatoes are valued, as crude material for the distillery, at 37.5 cents per bushel of 60 pounds. To this should be added 6.8 cents per 100 pounds, which is the estimated value of the spent material, as a cattle food.

The importance of the distillery as an agricultural industrial factor on this estate is readily indicated by its location. It was erected 25 years ago next to the old cow stable, and has a mash-tub capacity of 385 gallons. It was operated not with reference to reducing the cost of operation to a minimum but to spreading the production of the spent mash over as long a period as possible. Being an old distillery, it has but few modern improvements. Although it is equipped for a fourfold operation, it was operated only twofold, for the reason that while the Government allows the agricultural distilleries 249 days for operation, the allotment assigned by the Central Association to this distillery for the year 1907-8 was only 10,825 gallons of alcohol. On this quantity a tax of \$12.50 had to be paid. On the excess distillation, that is, on all alcohol produced over this quantity, there was a tax of \$17.50.

The 250 acres (400 Morgen) of potato land yielded on an average from 200 to 240 bushels of potatoes per acre, or about 50,000 to 60,000 bushels for the whole area. Of this total, about 1,850 bushels were used for table purposes on the estate.

When harvested, the potatoes were roughly sorted in the field. Those which were to be sold at once were shipped to Berlin, and the balance were stored in the fields, to be brought to the distillery as needed. The use to which these were to be put and the time

when they were to be used depended in part upon uncontrollable factors, such as their keeping qualities and the market price.

With this in mind, it becomes apparent why the distillery should have a fourfold equipment and also why at some times it should be run as a twofold operation and at other times as a threefold operation. These considerations also make it clear that for the sake of the cattle, as well as for the purpose of saving rotting potatoes, an excess distillation, on which the direct profits are greatly reduced, may be produced in a given campaign (distilling season).

To summarize: The Dahlem estate is operated as a dairy farm. Cattle are not raised, but cows and oxen are bought and as soon as their services cease to be remunerative are sold to the greatest advantage. Grain is cultivated with the dairy system in view. The straw is used for bedding cattle, and the grain (rye and oats) is sold in Berlin, while the flour for home consumption is bought. Barley, of which about 575 bushels are needed for malting, is not raised, because the yield on the sandy fields is said to be too low. Russian barley was bought for the campaign of 1907-8. Potatoes are cultivated and the distillery operated with the same end in view, namely, to provide warm feeding material for the cows during as many of the cold months of the year as possible. The production of alcohol, therefore, is conducted only as a side issue.

It is for this reason that the State has regulated the tax on alcohol as it has with reference to agriculture. A distillery operated like the one at Dahlem could not compete with a large modern plant in which the cost of production is reduced to a minimum. And yet the Dahlem distillery, small as it is, had as its "Kontingent" at that time four times the quantity assigned to what may be called the small agricultural distilleries, and more than the maximum for that class.

The small distilleries producing 10,000 liters (2,641.75 gallons) or less of alcohol pay nothing under the progressive tax (Brennststeuer). Indeed, the distillery at Dahlem, as well as all agricultural stills, does not pay this tax on the first 10,000 liters which it produces. On each additional 10,000 liters the tax increases. Only the mash tax is paid on the first 10,000 liters, and later, when the alcohol is released, if it is to be used for beverage purposes, the delivery tax (Abgabesteuer) is paid.

While each distillery has the right to hold back certain quantities of alcohol for technical purposes, this privilege is not exercised at Dahlem. The machinery operated on the estate is run by steam or electricity—by steam when such can be conveniently had from the boilers of the distillery, and by electricity when the cost of keeping up the steam would be too great for the services rendered. The prox-

imity of the estate to Steglitz makes electrical service convenient not only in the distillery but also in the creamery and in the grain shed for thrashing, etc. We have here an instance in which the most expensive kind of power is preferred, because it is cheaper for the service to be rendered than the power obtained from the alcohol manufactured as a by-product on the estate itself.

At the time of the visit to Dahlem the personnel of the estate consisted of 140 persons: Seventy "Einheimische," that is, such as are at home on the estate or in the neighborhood; and 70 "Auswärtige," that is, imported labor (largely Poles). There was a superintendent and three assistants. The superintendent is a sort of engineer who has general charge of the machinery. To this he can direct more of his time during the summer months. When the distilling operation is but twofold the distillations are ended by noon or shortly thereafter, so that his afternoons are available. When the operation is fourfold the working day lasts from 5.30 in the morning to 6.30 in the afternoon without interruption. It is estimated that the distillery is operated about 50 days.

DAHLEWITZ.

The station of Dahlewitz lies about 12 miles south of the Potsdam Belt Line Station of Berlin (Potsdammering). A 15-minute walk from the local station brings one to the former "Rittergut" or manorial estate.

At the time of the liberation of the serfs the original estate was partly parceled out. One-fourth was assigned to the village, another fourth to the former serfs, and the remainder, roughly estimated, constitutes the present estate. This was bought about 1879 for the present owner. At that time the distillery was reequipped, a large brick warehouse was constructed for grain, press cake, etc., and at the time of the visit a part of the old homestead was being rebuilt. It was said that the buildings on the farms, with their equipment, represented as large a value as that of the land.

The estate comprised 1,360 acres (550 hectares), of which, however, about 123 acres were leased to others. Of the remaining 1,237 acres, 1,114 acres were under cultivation, and 123 acres were used as meadow. These figures do not include the forest land belonging to the estate.

Of the 1,114 acres of cultivated land, 395 were for potatoes, 370 for winter rye, 247 for barley and summer oats, and 102 for clover, beets, etc. One acre of potato land yields about 297 bushels of potatoes, making a total of 117,315 bushels for the entire area cultivated. Of this amount, about one-third were small and defective potatoes, which were used in the distillery. Of the remaining two-thirds of the crop, part was sold, part kept for seed potatoes, and

part distributed among the workmen for use as food or to be fed to the pigs.

The grain for the most part is sold in Berlin, the straw being kept for bedding, etc. Whereas at Dahlem barley was not raised but had to be bought for the distillery, at Dahlewitz more than the quantity required for the distillery is raised, the surplus being sold in Berlin. In the malting process, oats are used with the barley in the proportion of 1 to 3. The grain is not mixed in this proportion at the time of malting, but when it is sown in the spring. It is believed that the natural mixture is better for the process of malting than the artificial mixture.

There were on the estate at that time 100 milch cows, 20 draft oxen, a considerable number of calves, 26 field horses, 6 coach and riding horses; also pigs and 300 chickens.

While the estate was run largely as a dairy farm it was by no means as exclusively such as the Dahlem estate. The cows were allowed to calve twice before being disposed of, the bull calves were sold when two weeks old, and the others were raised. Thus the stock was replenished on the estate. The calves were pastured for a part of the time, but the bulk of the 123 acres of meadow land was used for hay (Heuwiese). The cattle bred were the black Dutch.

All of the buildings looked very substantial, but the distillery, which was about 80 years old, was of a specially heavy construction. The interior was rebuilt about the time the present owner took possession. Most of the parts, therefore, are modern, and the general impression was very favorable, although naturally the arrangement is not as convenient as it might be, because it had to be adapted to the existing space. From the malting vaults to the receiving tank of the finished product everything had the appearance of order and cleanliness.

*One fact observed was of special interest as showing the operation of the method of taxation. The agricultural distillery is still taxed in part in accordance with the mash-tub tax laws. This law has been regarded as of special benefit to the distilling industry because it stimulated a number of improvements, as, for example, the thick mash. In order to utilize the mashing space to the utmost, this distillery has a contrivance which removes the skins, etc., from the mash, thereby slightly reducing the volume. While such a contrivance would not be necessary in the United States, it shows how even in one of the smaller distilleries every step is taken to reduce the tax to be paid.

The capacity of the mash tubs is about 580 gallons (2,200 liters) per tub. About 500 tubs are fermented during the distilling season of 8½ months, using a twofold operation. About 1,215 gallons of spent mash are obtained daily, so that with 100 milch cows each cow

receives from 10 to 13 gallons of spent mash daily. The daily average yield of milk per cow is about 2.3 gallons.

Five men are employed in the distillery—one master distiller, one assistant, two laborers, and a fireman. The master distiller is also a sort of general-utility man, having general charge of all the machinery, the superintendence of the buildings, etc. Moreover, he must be something of an electrical engineer, as he also has charge of the dynamos used for both light and power, including field power. Here, as in Dahlem, no alcohol is used on the estate for technical or industrial purposes, electricity and steam being employed.

In this connection attention should be called to the electric railway operated on the estate. It has already been stated that it is about a 15-minute walk from the station to the estate buildings. These buildings are connected with the State railway by a track on which cars are hauled by an electric locomotive. Thus coal is brought directly to the distillery, and the alcohol, when released by the revenue officer, is hauled by rail in carload lots directly to Berlin, each car containing about 15 barrels having a capacity of about 119 gallons each.

Another matter of general interest is the system by which the accounts are kept. These are systematized, it would seem, by accountants of the agricultural society. Thus the dairy was charged with \$2,875 for the previous year, including liberal items for fodder raised on the estate, for management, etc. If, on an average, 237 gallons of milk are obtained daily and 210 gallons are sold in Berlin at a little over 5 cents per quart (0.25 mark per liter), the income from this source may be estimated at \$42 per day, to which should be added the price obtained for the fattened cows when they cease to be valuable for milking purposes.

According to the statement of the owner, the distillery in itself does not pay, but when it is regarded as part of the entire estate it does pay.¹ In the foregoing estimate of expenditures of the dairy business of the estate, the distillery receives a credit of 4.1 cents for the spent mash derived from every bushel of potatoes used.

The owner stated that in spite of the fact that the estate has 100 milch cows, 40 oxen, and 32 horses, besides calves, pigs, and chickens, he is still compelled to buy stable manure. In addition, he uses large quantities of artificial fertilizers, a fair-sized building being devoted to the latter. The soil about Berlin is very light and sandy, and evidently needs much stimulation to produce crops that it will

¹ Recently Prof. Delbrück warned against trying to introduce the manufacture of alcohol on too small a scale. In this connection he has figured out the cost of a gallon of alcohol when made in a small distillery and compared it with the cost of the same quantity when made in a large distillery. These figures, he said, were decidedly against the small distillery and were used by others as an argument against the agricultural distilleries. The justification of the small agricultural distilleries lies in their relation to agriculture as a whole.

pay to handle. Whether it would pay to raise grain so near Berlin without the tariff on cereals, the writer does not know.

The personnel of the estate of Dahlewitz consisted of about 30 men and 40 women. During the potato harvest 40 persons are added to this number, and during the winter it is reduced by 30 persons. During the potato harvest the children help the adults, who are paid for their work by the hundredweight of potatoes handled and not by the length of time consumed. In addition, the children are also employed during the summer afternoons to pull weeds. A number of families reside on the estate, and about 30 of the employed are outsiders (Poles, etc.).

DOMINIUM NEUGUTH-HEINZENBURG.

A 4-hour ride on one of the fast trains between Berlin and Breslau brings one to Liegnitz. If it were not for the pine forests most of the country southeast of Berlin would seem like a large sand waste from which people here and there are trying to make a bare living. It is really necessary to spend the larger part of a brief winter's day in traveling through this country in order to appreciate what has been accomplished, for example, at Neuguth.

From Liegnitz it is a good half-hour's ride by rail to Leuben, a quaint old Silesian town. From Leuben it is a 2-hour ride by wagon to the Dominium Neuguth-Heinzenburg. The dominium, having been enlarged by the purchase of ten small peasant farms (Bauerngüter), now comprises over 5,670 acres of land (9,000 Morgen), of which about 2,835 acres (4,500 Morgen) are forested, mostly with pine. Of the slightly larger area not forested, 2,205 acres (3,500 Morgen) are plow lands (Ackerland), 787.5 acres (1,250 Morgen) are meadow land (all hay), 25.2 acres (40 Morgen) are occupied by ponds or very small lakes, and 63 acres (100 Morgen) are garden land.

Diversified farming is practiced. During the season of 1907 the crops were as follows: Rye, 756 acres; potatoes, 315 acres; oats, 157.5 acres; wheat, 63 acres; barley, 63 acres; lupine, 220.5 acres; saradella,¹ 189 acres; clover, 157.5 acres; beets, carrots, etc., 63 acres.

The inspector, who had served an apprenticeship of five years with a scientific agriculturist from Halle, stated that he regarded 315 acres of potatoes a necessity in order to secure proper soil conditions for the necessary rotation of crops of the estate. Every third year cultivated crops (Hackfrucht)—that is, potatoes or beets—should be used. The result is that 350 pounds more of grain are harvested per acre. On the other side of Leuben, where the soil is heavier and admits of the cultivation of sugar beets, an increase of 525 pounds of grain is obtained.

¹ Saradella is preferred to lupine for light soil.

The average yield of potatoes was over 291 bushels per acre, resulting in a total of 91,660 bushels. Of this amount, 55,110 bushels were used for the distillery, 7,350 bushels were reserved as seed potatoes, 18,300 bushels were distributed among the laborers, 1,800 bushels were sold, and 9,100 bushels were used as feed. In the year 1907 the potatoes for the distillery were valued at 18.6 cents per bushel, including the spent mash. These potatoes were not sorted.

The new distillery, constructed by a Breslau firm after the plans of the building section (Bauabteilung) of the Society for Spirit Manufacturers in Berlin, cost about \$42,500. The net profits in 1906 were \$1,200, but the computation does not include the interest on the investment and a 10 per cent depreciation of machinery, due to wear and tear. According to the inspector the value of the distillery, therefore, lay in the utilization of the potatoes whenever desirable. This crop, however, as has been pointed out, is a necessary factor in the proper cultivation of the light soil.

The allotted output of the distillery is 12,150 gallons.¹ The mash-tub capacity is about 790 gallons with a twofold operation and with the possibility of a threefold operation. Eight gallons of spent mash are fed daily to each milch cow and about 59 gallons to the young stock. In addition to the spent mash, hay, etc., each cow gets the following ration: 1 pound of wheat husks, 1 pound of peanut cake, 1 pound of cottonseed cake, and 1 pound of sunflower cake.² As a result of this plan of feeding a daily average of over 2 gallons of milk per cow is obtained, averaging $3\frac{1}{2}$ per cent of fat. The milk is sold to a dairy which pays in accordance with the fat content.

About 660 gallons of milk are used on the estate, and about 50,190 gallons are sold to the dairy in Polkwitz (about $4\frac{1}{2}$ miles distant) at an average of 2.5 cents per quart. The owner, who is also one of the principal stockholders of the dairy, receives between \$200 and \$225 in dividends as additional profit.

In addition to the 100 milch cows there were on the estate 150 head of young cattle, 50 draft oxen, 40 horses, 500 sheep, 100 chickens, and 100 geese. Pigs are kept on the estate only by resident servants. The value to the estate of these numerous animals can best be appreciated if one sees what quantities of manure are spread over the fields. The carting is done by the men and the spreading by the women and girls.

¹ Formerly it was 15,850 gallons, but it was diminished because of the erection of new distilleries. This increase in the number of agricultural distilleries would seem to indicate that the estate owners are convinced of their value, even though the benefit derived be but indirect, at least in certain years.

² These materials are now purchased through a large corporation, an agricultural concern with headquarters at Berlin, which not only has branch depots in all large railroad centers but which also controls both price and quality by having analyses made. This cooperation has proved a serious loss to certain traders but is of benefit to agriculturists.

To judge accurately and in detail the agricultural value of these estates might be difficult even for an expert agriculturist. However, a layman can see what is being done on such an estate and can comprehend the difference between the fields which are carefully fertilized and cultivated and the broad sand wastes through which one passes by rail. But these estates are not merely farms—that is, they do not serve agricultural purposes solely. They are the homes of the nobility, at least in great part, and while some of the nobility no doubt are good agriculturists, others (and even the good agriculturists themselves) regard their farm profits as secondary to game preservation. This was well illustrated by conditions seen at Neuguth.

This was the first of the estates visited by the writer on which he found that at least a small part of the alcohol produced was used industrially. The owner has a high-speed automobile which he runs with alcohol, and in this way more than 1,000 gallons (4,000 liters) are consumed annually. The castle, the distillery, the wagon barn, the cow stable, the saw mill, and the carpenter shop, are lighted by means of alcohol. The distillery has an alcohol motor for pumping water and for running the grist and flour mill during afternoons when the steam is kept low and also during the summer months when there is no steam. The alcohol consumed on the estate annually exceeds 5,000 gallons.

TREBEN.

The *Dominium Treben*, owned and managed by Baron von Leesen, is about an hour's ride by wagon from Lissa, in the Province of Posen. Schwetzkau, a large village with a post office, maintains communication with Lissa by mail coach. The Province of Posen is that part of the former Kingdom of Poland which in the partition of that State was assigned to Prussia.

The soil appears to be of a somewhat heavier quality than that of Neuguth, corresponding possibly to that found beyond Leuben, since it admits of beet cultivation; but evidently it is much lighter than the soil of the typical beet sections to the west of Berlin toward Magdeburg.

In the absence of the inspector the superintendent of the distillery acted as guide. He also serves in the capacity of paymaster and subinspector at Treben. The inspector has general charge of the two estates, Treben and Petersdorf, which together constitute the "dominium."

The data which were obtained were given by the superintendent.

The distillery was erected at a cost of between \$19,000 and \$21,500, and was completed in 1906. Although not as fine a structure as the

one at Neuguth, it was equipped very much along the same lines, having been built by a Westphalian firm in accordance with plans and specifications provided by the building-technological division of the Society of Spirit Manufacturers. In completeness of detail it was not as perfect as the one at Neuguth, but it showed that a fine, up-to-date distillery can be built for little more than half the cost of the one in Silesia. The mash-tub capacity is about 792 gallons per tub and the operation a double one. For each operation 110 bushels of potatoes are used, making a daily consumption of 220 bushels. The spent mash (about 1,500 gallons) is fed to the cattle at Treben and Petersdorf.

The distillery had no allotment, but received a rebate for 264 gallons. During a run of six or seven months under the double operation they expected to distill about 26,400 gallons of alcohol. None of this was used technically on the estate. The employees of the distillery consisted of a master distiller and three assistants.

The two estates of Treben and Petersdorf comprise about 1,575 acres (2,500 Morgen) of cultivated land and the same area of wooded land. On the two estates about 20 men and 50 women are employed. During the summer months there are 15 additional laborers (Galicians).

At Treben there are about 60 milch cows, 16 draft oxen, 14 horses, and from 160 to 180 pigs. The number of animals at Petersdorf was not ascertained. The young cattle are kept there in addition to some milch cows. The potato waste from the distillery is fed exclusively to the cattle, the pigs receiving raw potatoes as part of their food. The amount of milk and the price received therefor were not ascertained. The bulk of the milk was hauled to the dairy, a distance consuming about two hours.

Here also the distillery was not regarded as a paying institution in itself, but its indirect value was twofold:

(1) It put the dairy on a better financial basis, because the cows and oxen after having served their purpose were in fine condition to be sold. The cattle were also a necessity because of the manure they furnished.

(2) The potatoes in this case were more valuable when converted into alcohol than when sold as potatoes. In the fall of 1907 they were valued for alcohol purposes at 17 to 18 cents per bushel, whereas in the market they brought only 9 to 10½ cents per bushel of 60 pounds and had to be hauled a considerable distance. The potatoes in turn were needed for a proper rotation of crops.¹

WEIHENSTEPHAN.

The estate of Weihestephan is the seat of the Royal Bavarian Academy for Agriculture and Brewing. It is located just outside the village of Freising, in Upper Bavaria. Its new experimental

¹ Beets were also cultivated, but they had to be hauled to the nearest sugar factory, a distance consuming about two hours' time.

distillery is equipped with two distilling outfits: (1) A modified hand equipment—that is, a still ordinarily operated without machinery, such as pumps, etc., and therefore of necessity interrupted after each operation—and (2) a modern equipment on a larger scale. Even this, however, is smaller than a minimum-efficiency apparatus should be in accordance with the computations of the engineering department of the Institute for Ferment Industries at Berlin.

In order to get the Bavarian distillers to adopt the plan of alcohol allotment, various concessions had to be made. Therefore, they occupy a favored position of which the northern distillers are envious. They are also permitted to utilize maize (from the Balkan States) whenever the potato crop is insufficient. They are, therefore, not agricultural distillers in the strict sense of the legal definition of this term as used in Prussia. Moreover, it has been the tendency of the State governments to favor the small distillers in proportion to their smallness. Whereas in the northern States and Provinces the hand equipment has been replaced almost entirely by mechanical operations, in Bavaria there are still a number of small distilleries. This appears to be due to two or three factors, namely, to the large number of small farms and to the conservatism of the farmers.

At the close of the eighteenth century the central Government of Bavaria permitted the villages to dispose of their communal property in small parcels to the villagers, a policy which was also adopted by other German States, but in no State was this process carried out in so short a time as in Bavaria. The result, from an agricultural and economic point of view, was very detrimental. A single instance may here be mentioned. Large tracts of land formerly used as meadow were placed under cultivation, and in a short time the cattle of Bavaria were literally decimated. The reaction on agriculture as a whole was harmful.

As an indirect outcome of this condition, the Bavarian system of agricultural education during the period near the middle of the nineteenth century lagged far behind that of other German States, although at the beginning the Bavarian Government had made a good start in the education of the newly created farmers. A hundred years ago their education by means of bulletins, etc., was out of the question, because the large majority here, as in many other places, could not read. Systematic education was even less possible. Therefore, education by example had to be resorted to, but even then the farmers availed themselves so little of the opportunity that at Weihenstephan it was abandoned for a time.

This condition of affairs not only explains why there are so many small distilleries in Bavaria, but it also explains the attitude of the scientific institutions which constitute their technical advisers. Side

by side, therefore, with a rational modern equipment one finds in the experimental distillery at Weihestein a modified hand equipment—that is, a small plant run in part by machinery and with a still operated by steam and not by direct fire. The object of this equipment is not to encourage the farmers to introduce even this improvement on their antiquated equipment, but to demonstrate that with their inefficient system of management they secure only a part of the alcohol which they ought to get. Even when this modified plant is operated under the most favorable conditions imaginable, the maximum yield on the average is but 10 per cent, instead of 12.

In addition to this small apparatus, the new experimental distillery is equipped with an outfit which has a mash-tub capacity of 275 gallons, worked on the single-operation basis. A threefold operation is possible and would be more rational.

PERLACH.

Perlach is a village 10 miles southeast from Munich, lying in the same broad valley in which that city is located. The Bavarian Alps, 30 miles to the south, form a beautiful panorama. The valley is covered with but a thin layer of soil, beneath which is gravel.

The light soil about Munich is especially adapted to potato cultivation, the Freising edible potato being especially esteemed. This soil needs considerable manure, which accounts for the fact that the development of the alcohol industry about Munich since 1850 has been in connection with the dairy farm and with the cultivation of potatoes.

Perlach afforded an especially favorable opportunity for studying in a practical way the conditions in Bavaria. The distilleries here found were of three classes: (1) Four small distilleries (the so-called fusel distilleries), (2) three medium distilleries with stills operated by steam rather than by direct fire, and (3) one cooperative distillery (Genossenschaftsbrennerei), the largest in Bavaria. These three classes, therefore, which mainly come into consideration in Bavaria, could here be studied side by side, which was exceedingly satisfactory, because a direct comparison under like conditions was thus made possible. Had they been separated by only a short distance, minor factors might have entered which would have been difficult to balance properly.

One of the four fusel distilleries was visited first. Concerning the estate on which this distillery was located a number of details were secured. The farm consists of 84 acres of plowed land (100 Tagewerk) and somewhat less than 33 acres (40 Tagewerk) of meadow and forest. About one-third of the cultivated area, that is, 25 acres, was planted with potatoes, the harvest of the previous season having

amounted to somewhat less than 5,512 bushels (1,000 Scheffel). All of the potatoes except those reserved for the house and for seed purposes were used in the distillery. One large structure serves as home, barn, granary, etc., but the distillery is in a separate building. The equipment dates from 1848 and is of the Pistorius type. Work began at 2.30 a. m., and the pay was \$2.38 per week with meals while at work. The season began in September and was supposed to last until May.

About 20 bushels of potatoes were used each day. After being steamed they were mashed in a hand mill, the saccharine fermentation was started with malt prepared in the cellar of the house, and the alcoholic fermentation was started with brewers' yeast. The capacity of the three tubs amounted, respectively, to 246, 272, and 248 gallons. The yeast, which was kept in a large vat outside the building, looked more like the liquid in a manure pit than like any well-prepared or preserved yeast. From the fermenting vats the mash was lifted by means of buckets into a trough which carried it to a warming apparatus (Vorwärmer). This in turn served to condense the water from the still, thus concentrating the spirits. The large flat still was heated with direct fire. The distiller's book showed that the average yield of alcohol was from 5 to 7 per cent. The strength of the spirits obtained was from 48 to 50 per cent. Two revenue officers, who were visited later, stated that 5 per cent was rarely, if ever, obtained, at least in their district.

The waste material went to the barn, where it was fed to the cattle. At that time 20 milch cows and 5 oxen were being fattened. About 150 to 160 pounds of milk a day were obtained, which sold for 3.6 cents per quart to the milk seller, who peddled it in Munich. Potatoes were valued at the cooperative distillery at 19 to 20 cents per bushel. Alcohol sold at 61 cents per gallon, with a tax of about 9.9 cents per gallon.

As to whether the distillery paid, the distiller had no idea other than that the spent mash or waste was necessary for the cows. That the same by-product could be had from the cooperative distillery he evidently did not consider.

Of the medium-sized distilleries only one was visited. The farm on which it was located had about 247 acres of cultivated land. There was a very large building, which served all purposes from a dwelling for the family to a stable for the animals, and it all made an excellent impression.

On the whole, the conditions on a large farm differ but little from those observed on the small estates in the North. The main difference is probably that the proprietor himself works with all the members of his family. The distiller on this farm had no assistant, but

possessed sufficient technical skill to prepare the yeast himself. He claimed to obtain a yield of 10 to 11 per cent of alcohol, which compares very favorably with that of the smallest distilleries. The strength of the alcohol obtained was about 90 per cent, somewhat lower.

The cooperative distillery at Perlach has existed as such since 1886. The distillery itself was erected and equipped in 1880 by private means at a supposed cost of about \$95,400, and was purchased by the cooperative corporation in 1886. A share in the cooperative society consists in the right to draw 264 gallons of spent mash, and represents a stock value of about \$600. There are 20 of these shares, representing a total stock of about \$12,000. The plant was bought for about \$28,620, there being an original indebtedness of about \$16,600. The actual value of the plant was said to be four times the sum paid for it, but the stock had not been watered, neither did the books of the company show a higher value. Premiums were paid in a semiprivate way.

While there can be but 20 shareholders, a share may be divided among two or more persons, only one of whom, however, can be the actual shareholder, the others being associates. Thus, the smaller farmers were enabled to take a part share, the total number of participants at that time being 36, some of whom had only a tenth of a share. For each tenth in which a farmer participated he drew 26.4 gallons of spent mash, as already indicated. Potatoes were bought outright. During that season the prices fluctuated but little, lying between 19 and 26 cents.

The mash capacity of the distillery is 1,268 gallons per tub. The allotment admits of a threefold operation for two days, alternating with a $3\frac{1}{2}$ -fold operation every third day. This was the best utilization of an equipment that had yet been seen. It was made possible, no doubt, because of the fact that the Bavarian distillers were favored with a relatively high "Kontingent" in order to get them to cooperate with the distillers of the northern States and Provinces. Of this the northern distillers constantly complained. Besides, in the distribution of the "Kontingent" every five years the 36 farmers belonging to the cooperative plant naturally exercised a greater influence collectively than if each one were fighting for himself and against his 35 neighbors. The yield of alcohol averaged 12 per cent, and the spirits obtained averaged 90 per cent.

Owing to a variety of circumstances, such as improvements, the low price of alcohol, etc., the company paid no cash dividends that year. Each farmer, however, had received his spent mash, which was valued at 2.7 cents per gallon. The farmers also received 1.2 cents more per bushel for their potatoes than did the outsiders. If potatoes gave out they could use maize, of which the distillery had

used in one year as much as 80 carloads of 393 bushels of 56 pounds each. It was expected that they would use only about 30 carloads in 1907, partly because of the good crop of potatoes and partly because of the high price of Roumanian corn. This corn, which is said to be richer in starch than the American La Plata corn, had formerly cost but \$1.30 per 100 pounds, but at that time the price was \$1.83 per 100 pounds. This increase was partly due to an increase of 71.5 cents in the duty on foreign maize.

If, as stated by the superintendent, the dividends had been only as high as 4 per cent in good years, the high value of the stocks could be explained only by the value placed on the spent mash.

The superintendent of such a distillery, as may be expected, is a very different sort of man from those found in the distilleries which are hand equipped or even in the medium steam-operated plants. As has been pointed out, the larger distilleries are taxed much more heavily, and in order to obtain the same returns on the investment they must be operated much more economically and must produce a larger percentage of alcohol.

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WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

April 13, 1915

MORPHOLOGY OF THE
BARLEY GRAIN WITH REFERENCE TO
ITS ENZYM-SECRETING AREAS

By

ALBERT MANN, Plant Morphologist, and H. V. HARLAN,
Agronomist in Charge of Barley Investigations

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INTRODUCTION.

The value of the barley crop to the American farmer depends upon two factors, the yield per acre and the price per bushel. An increase of revenue is as readily effected by one as by the other. The yield is necessarily an agricultural problem; the price is also, within certain limits. Although the daily price of any market product ordinarily varies over a considerable range, higher values are placed upon those offerings which most perfectly meet the requirements of consumers. A superior quality is the equivalent of a greater quantity. The nearer a farmer can come to producing a product ideally suited to its uses, the higher will be the price which he will be able to command.

By far the greatest demand upon the barley crop is for the purpose of malting. This operation consists essentially in the breaking down of the cell walls of the endosperm of the barley grain so as to leave its starch grains exposed to later enzymatic actions, and also in the abundant production of these enzymes, both the diastatic and proteolytic. The abundant formation of diastase has long been con-

NOTE.—This paper is intended for distribution to agronomists, station directors, brewery chemists, and selected maltsters.

sidered to be one of the most important functions of the malting process. In small-berried malts the excess of diastase is often used in brewing to convert quantities of inert starch in addition to that found in the grain itself. In some large-berried malts it may be so used; in others, it is best used in conjunction with the other ferments to convert a large endosperm and thereby obtain a high percentage of extract.

The possibility of this improvement in quality was the cause of the special study made of this grain. Early in the investigation it was realized that the desirability of any barley must rest largely on its morphology, because the physiological changes must owe their origin to morphological sources. An extensive study of the barley grain, both at rest and in germination, was outlined. It was later found that the investigation had to be extended to include the embryology of the grain, in order to explain certain features of its resting condition. The Office of Foreign Seed and Plant Introduction, where a large part of these investigations was carried on, was of great service in obtaining for study samples of barleys from almost every country of the world. The primitive barleys of Asia and the most specialized productions of Europe were compared in structure and in the details of germination. A persistent agreement between malting quality and morphological structure was found throughout the observations, and the conclusions pointed toward a hopeful method for securing a better quality in this grain.

A brief report which discussed the secretion of diastase and cytase in the barley grain was made by the senior writer¹ in 1908. Such statements in this paper as relate to the histological phase of secretion are also based upon his studies.

STRUCTURE OF THE BARLEY GRAIN.

A ripened grain of barley is a very complex structure. It contains not only the usual essential members of growth, but certain adhering layers of tissue which remain from organs functional at earlier periods of development. The gross anatomy of the grain may be separated into three divisions: The seed proper contains the young plantlet and the food stored for its use in germination. Enveloping the seed is a covering of several layers which, because it includes the remains of both the ovary walls and the integuments, has been given the name of caryopsis. In most of the cereals this caryopsis is freed from the glumes or floral leaves by thrashing. With barley this is not usually the case. In all but a few forms the glumes are grown fast to the caryopsis, and the grain presents the appearance shown in figure 1. While the relation of the parts is more apparent when considered in the order enumerated, a study of the structure more logic-

¹ Mann, Albert. A new basis for barley valuation and improvement. U. S. Department of Agriculture, Bureau of Plant Industry Circular 16, 8 p., 3 fig., 1908.

ally proceeds from the glumes inward. The glumes, the seed coat of the caryopsis, and the seed proper, each consists of several kinds of tissue.

THE GLUMES.

The outer surface of the glume is protected by a heavy cuticle. The cuticularization does not penetrate deeper than the first row of cells. The three outer layers of cells have heavily reinforced (sclerenchymal) walls, while the underlying layers are thin walled and more variable. They are usually three or four in number. The vascular bundles of the glume are normal leaf bundles

THE SEED COAT OF THE CARYOPSIS.

The term "seed coat of the caryopsis" is here used to include groups of tissues from three separate origins: The pericarp, the testa, and the semipermeable membrane. The pericarp is the remains of the ovary wall. Its outer layer lies flat against the glume and is united with it. Beneath the layer in contact with the glume are several layers of parenchyma, consisting of much flattened and often almost disconnected cells. Below this are two layers of parenchyma that formerly contained chlorophyll. Though equally flattened through pressure, they are in much better condition as a layer. The cells of this tissue are almost at right angles to those of the main parenchyma region and tangential to the grain. On the inside of the pericarp are sometimes found scattering fragments of the inner epidermis of the ovary, their cells also elongated lengthwise with the grain.

The testa is the remnant of the inner of the two integuments that once existed inside the ovary wall, the outer one having disappeared. The cells of the testa are crushed almost to the point of disappearance, being represented in the ripened grain by a mere line. In intimate contact with the testa and much better preserved is the investing membrane of the nucellus. It consists of moderately thickened cells flattened by pressure. On the inside of this are occasional patches of partly reabsorbed cell walls, remnants of the nucellar tissue. According to Brown,¹ the investing membrane of the nucellus probably forms the semipermeable membrane, though the inner integument may also be concerned.

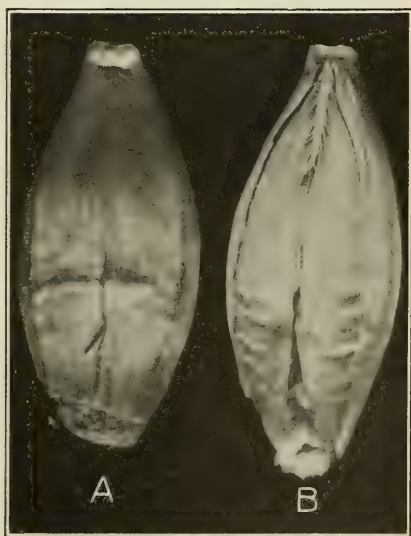


FIG. 1.—A grain of 2-rowed barley: A, Dorsal view; B, ventral view.

¹ Brown, A. J. On the existence of a semipermeable membrane inclosing the seeds of some of the Gramineae. *Annals of Botany*, v. 21, no. 81, p. 79-87, 1907.

THE SEED PROPER.

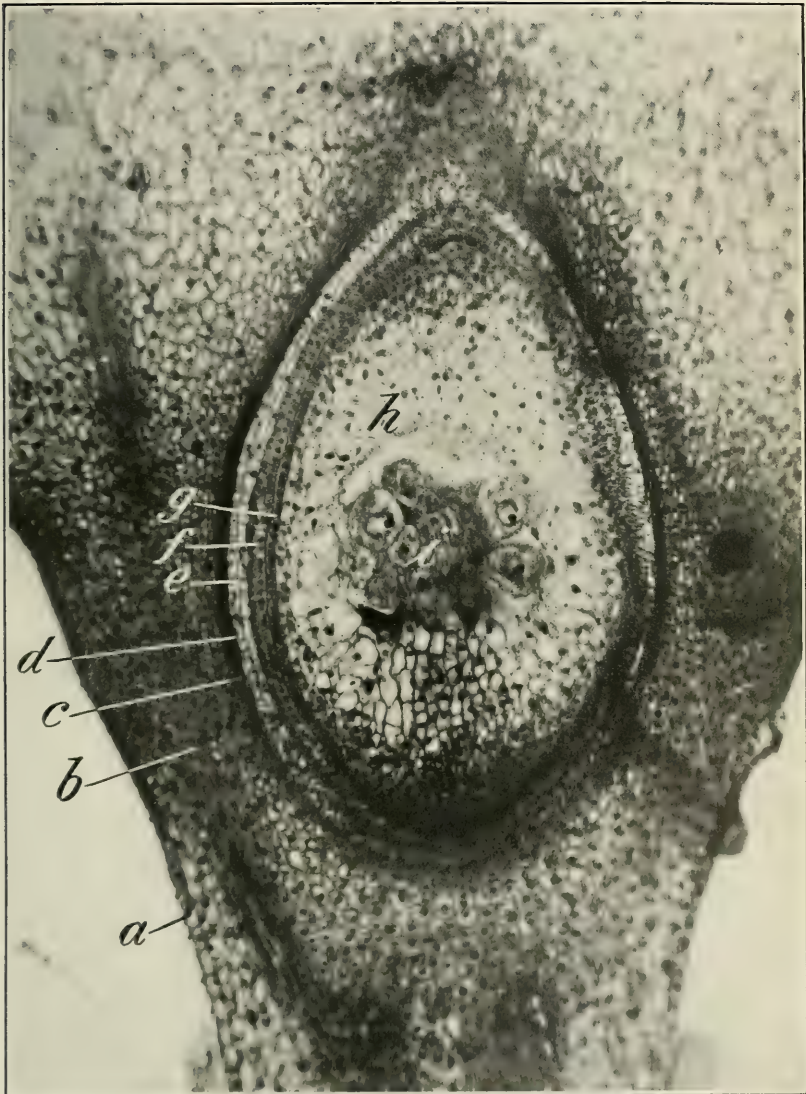
The external layer of the seed proper is the aleurone layer. It assumes a greater importance in barley than in other grains. It normally consists of a stratum of two or three rows of cubical cells gorged with protein contents. Their appearance shows them to be cells of unusual vigor and vitality. The greater part of the space within the aleurone layer is occupied by the starch endosperm. This is, as in all grasses, a typical storage tissue. Its cells are thin walled

and packed with starch granules. The nuclei are feeble and distorted by the pressure of the accumulated starch. At the proximal end of the starch endosperm and partly embedded in its tissue lies the embryo, the morphology of which is observed with ease but interpreted with difficulty. From its nature, it must contain all the growing elements of the plant to be, as well as a number of modified organs. The embryo lies obliquely to the long axis of the grain, its growing point directed toward the distal end. The true vegetative point is inclosed within the first leaves of the plant. In barley these are twisted, giving rise to the term "acrospire" in place of "plumule." The plumule sheath surrounds all the upper vegetative portions. At the proximal end of the embryo is found a single main radicle. A short distance above, possibly at the first rudimentary internode, are five to eight secondary rootlets. When eight are present three are placed on either side and two toward the front. The space between the secondary rootlets and the growing point serves as a base for the attachment of the extra-



FIG. 2.—A high-grade barley grain with the glumes removed to show the embryo with its collarlike scutellum (s). The inner envelopes have been removed from the upper part of the grain.

embryonic tissue, the scutellum, or shield (fig. 2), which includes practically all the remaining tissue. The origin and significance of this body as well as of the epiblast (absent in this genus, but common in grasses) has been variously interpreted. The scutellum is, however, generally conceded to be an absorbing organ. It is made up of thin-walled cells with large nuclei. Its inner surface rests directly upon the mass of the endosperm, and this surface of contact consists of a layer of elongated cells placed endwise to both the endosperm and the rest of the scutellar body. This layer, which is known as the epithelial layer, plays, according to the observations of the writers, a large part in the chemical activities of germination.



PHOTOMICROGRAPH OF A LONGITUDINAL SECTION OF A BARLEY OVARY IMMEDIATELY AFTER FERTILIZATION.

The two plumose stigmas do not appear. *a*, Outer epidermis of ovary; *b*, colorless parenchyma; *c*, chlorophyll-bearing parenchyma; *d*, inner epidermis of ovary; *e*, outer integument of ovule; *f*, inner integument of ovule; *g*, external layer of the nucellus; *h*, nucellar tissue; *i*, group of endosperm-forming cells of the young embryo sac.

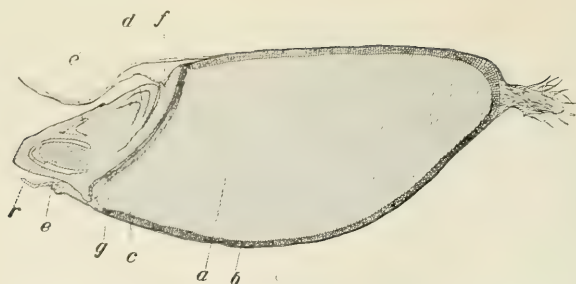


FIG. 1.—LONGITUDINAL (DORSI-VENTRAL) SECTION OF A MATURE BARLEY GRAIN.

a, Starch endosperm; *b*, aleurone layer; *c*, area of starch endosperm, adjacent to the scutellum, representing the initial stage of the corrosion of the endosperm. This took place at the close of the ripening of the grain. *d-r*, The embryo; *d*, plumule with investing sheath; *e*, primary, and *e'*, secondary, radicles; *f*, scutellum, the surface next to the endosperm covered with the epithelial layer (*g*); *r*, root cap of primary radicle.

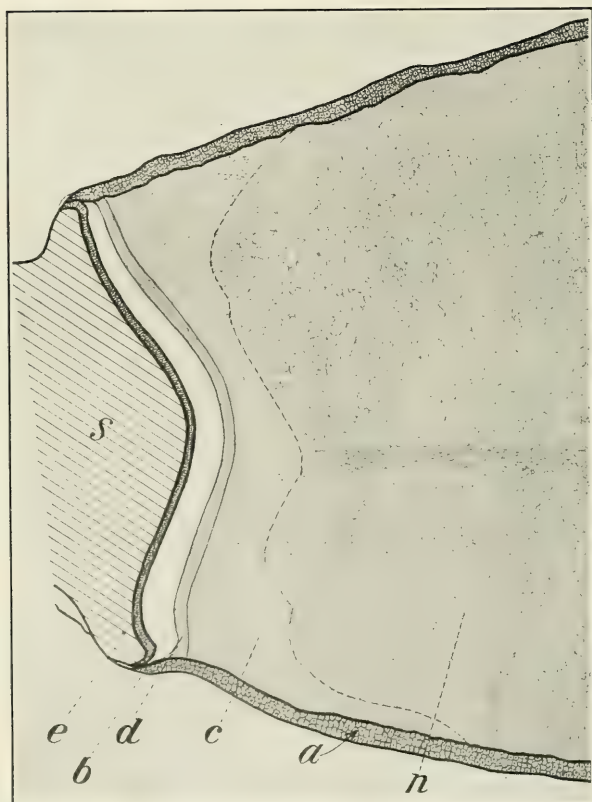


FIG. 2.—LONGITUDINAL SECTION OF BARLEY GRAIN, SHOWING THE STAGE OF ENDOSPERM CONVERSION AT THE END OF THE SECOND DAY OF GERMINATION.

The starch endosperm is being broken down in the dense areas directly in front of the epithelial layer, (*e*), of the scutellum (*s*), and more rapidly in the less dense areas adjacent to the aleurone layer, (*a*). *b*, Clear fluid area produced during germination; *c*, corroded area of starch endosperm; *n*, normal starch endosperm not yet attacked.

DEVELOPMENT OF THE BARLEY GRAIN.

An understanding of the office and behavior of the various organs of the barley grain is greatly facilitated by observations upon their origin and development. Some of these organs are functional throughout the existence of the seed; others important in the early stages afterwards disappear, while still others become so modified as to be serviceable in a totally different way.

The flower of the barley plant is inclosed within the flowering glumes, as in all grasses. It consists of a simple ovary containing a single ovule. The stigma is two branched and plumose. Three versatile anthers attached below the ovary fit into as many natural angles in the glumes. On the dorsal side of the ovary are two lodicules.

At the time of flowering, the ovary wall is a but slightly modified vegetative structure. It consists of the usual epidermis, a colorless parenchyma of several layers, a chlorophyll-bearing parenchyma, and an inner epidermis. The chlorophyll layer is the only one in any way exceptional. The cells of this lie with their long axes at right angles to that of the others and tangential to the grain. Inside the ovary are two integuments which probably act as conductive tissues to the growing pollen tube during fertilization. Each is formed of two layers of thin-walled cells. The cells of the outer integument are somewhat larger than those of the inner one and are much thinner walled. The contrast between the two integuments is very evident in Plate I. Inclosed by the two integuments is the nucellus, which is in turn surrounded by its own investing membrane, consisting of a single layer of cells. In the parenchyma mass of the nucellus is the embryo sac, which before fertilization contains the usual eight cells. At this stage of development the cells of all the tissues are filled with plasma.

After fertilization the ovary increases in length and width. As the essential parts of the developing seed are taking shape, certain now useless portions of the enveloping structures become modified and in some cases absorbed. The plasma gradually disappears from the cells of the outer integument, the cell walls become transparent, and finally dissolve and disappear. The inner epidermis is also absorbed, although not always completely, as traces sometimes persist at maturity. A little later, portions of the ovary wall begin to weaken. The starting point is usually just outside the chlorophyll layer, and the process advances outward through the overlying parenchyma layers. At maturity this tissue is represented by a compressed mass of almost disconnected cells. In the earlier stages of growth it is this reduction of tissue that establishes the "green ripeness" of Kudelka, the removal of the overlying cells bringing the chlorophyll layer nearer to the surface, thus intensifying the

green color. The chlorophyll-bearing cells themselves become somewhat thickened and remain plainly discernible as a layer, even at maturity. The inner integument does not disappear as does the outer one. The cell walls undergo considerable modification and the layer becomes crushed, so that it exists in the ripened fruit only as a dull brown line. It is in the investing membrane of the nucellus, however, that the greatest functional transformation occurs. The cell walls of this delicate tissue become thickened, and the layer quickly assumes, either independently or in conjunction with the inner integument, the functions of a selective semipermeable membrane. Brenchley states that even before the glumes are grown fast to the fruit it is necessary to prick through this membrane to bring about the entrance of killing fluids. The absorption of the nucellar tissue begins almost immediately after fertilization has taken place. It proceeds rapidly and is almost total, a small body persisting near the funicle and fragments of collapsed cell walls in chance locations elsewhere.

Of the tissues which envelop the seed, the semipermeable membrane is the only one performing more than mechanical service. On the other hand, all the growth within the embryo sac is of physiological purpose in one or more ways. There are three important structures—the aleurone layer, the embryo, and the starch endosperm (Pl. II, fig. 1). The three are associated in development and are intimately related in later germination and growth. Preliminary to fertilization, the nucleus of the embryo sac divides and redivides until eight nuclei are present. The egg cell and two companion cells locate near the micropyle. Two others unite to form a large nucleus near the center, while the remaining three, the antipodal cells, pass to the end opposite the egg cell.

Following fertilization, the egg cell begins the initial divisions of the growth of the embryo, but its development is less rapid than that of the large central nucleus, which is the source of the endosperm. The earliest and most vigorous cell division of the endosperm-forming tissue occurs near the distal end of the grain upon the ventral side and adjacent to the antipodal cells which, according to Johannsen,¹ have by this time increased to the number of 30 or thereabouts. After the first layer of endosperm cells has been formed, the growth continues radially toward the center of the grain. The mature stage is always found on the ventral side and particularly in the flanks of the furrow. It is only after the embryo sac is entirely filled with cells that the outer layer of the endosperm begins to differentiate. Although at this time starch grains are infrequent throughout the endosperm, its external layer begins to exhibit the proteolytic

¹Johannsen, W. Om Frøghviden og dens Udvikling hos Byg. Meddelelser, Carlsberg Laboratoriet, Bd. 2, Hefte 3, p. 103-133, 3 pl., 1884. (French ed., p. 60-77.)

character of the aleurone sheath. The first starch grains are formed in the older areas of the endosperm near the distal end of the grain. According to Brenchley,¹ this occurs on the sixth day after flowering and in the middle of the flanks of the grain. On the seventh day, scattering grains are apparent in two-thirds of the length of the grain. On the tenth day, the deposit is very heavy in the flanks and extends almost to the embryo. It is not until the nineteenth day that the main body of the starch is completed. The cells next to the aleurone layer are the last of the endosperm tissue to fill with starch.

Accompanying this infiltration of starch are certain modifications of the nuclei of the endosperm. Just before the first starch grains are formed the nuclei become granular. For a time they are full of vigor, with the starch grains arranged about them. As the process advances, the nuclei gradually become distorted by pressure exerted by the growing starch. The cells next the aleurone layer and near the furrow are affected much later and to a lesser degree. As above stated, the aleurone layer begins to differentiate soon after the embryo sac becomes filled with new cells. It consists at first of a single layer, increased to three as the endosperm mass grows. The cells are arranged radially and present about the same appearance in both cross and longitudinal section. In tangential section their arrangement is very irregular. Their contents quickly show the characteristic aleurone nature. The dense mass of glutinous and fatty compounds, the aleurone grains themselves, and the large nuclei are present in no other section of the endosperm. As the cells approach maturity the walls become very thick and are seen to be perforated with small canals.

It is only after the cells of the endosperm have divided many times and the endosperm mass is beginning to take shape that the embryo begins active development. At first it lies free in the sap at the lower end of the embryo sac. Gradually the endosperm becomes organized about it, and by the time the more prominent divisions of the embryo have become differentiated the two are in contact. The later growth of the embryo is at the expense of the starch endosperm and during germination their relation is that of parasite to host; but before the grain is matured this statement is not entirely justified, in that, although numerous endosperm cells are emptied of their contents and a mass of collapsed cell walls is crowded before the upper angle of the scutellum, their reduction takes place more in the manner of normal growth. The cell walls are not broken down, and the removal of the starch is effected by the processes typical of the diastase of translocation rather than by that of the corrosive action of digestion.

¹ Brenchley, W. E. Development of the grain of barley. *Annals of Botany*, v. 20, no. 103, p. 903-928, 22 fig., 1912.

Within the embryo various tissues arise. A primary radicle and from five to eight secondary rootlets, inclosed in their sheathing tissues, are directed toward the proximal end of the grain. The plumule within the plumule sheath points up over the endosperm toward the distal end of the seed. Attached midway between the root and plumule—that is, to the hypocotyl—by a wide ligament, or umbilicus, is the scutellum. This organ spreads out over the entire surface of the endosperm lying next to the embryo and has on its inner or adjacent surface a layer of specialized cells—the epithelial layer.

GERMINATION.

Germination is the continuation of the growth of the embryo, arrested at the time of the maturation of the seed. The first step in germination is a distension of the grain, due to the absorption of water. In the resting stage most of the tissues of the embryo are free from starch. When first brought under conditions favorable for germination the few starch grains present disappear. Very shortly, however, starch again becomes evident in tissues that were perfectly free from it at maturity. In the outer layers of the scutellum a marked deposit is soon apparent. As the process advances, the cells of the epithelial layer elongate slightly. Brown and Morris¹ noticed that one of the first changes in the grain was in the appearance of the protoplasm of these cells. In the resting state this is clear and finely granular. As the first steps of germination are in progress it assumes a much coarser character and the cell becomes cloudy. This condition obtains until the endosperm is almost entirely absorbed.

The first actual formation of new tissue takes place in the primary radicle. This breaks through the coleorhiza and is the first part of the plant to emerge from the grain. The secondary rootlets are slightly less advanced. The plumule develops more slowly, and under restrained malting conditions it may be several days in reaching less than the length of the grain.

In the endosperm, germination is, of course, a process of destruction. In the history of a single cell the walls first become thickened as if distended with water. The laminae become distinct, the walls become translucent, and disintegration sets in. Various investigators have asserted that a complete obliteration of the walls takes place, but the writers have not been able to arrive at this conclusion, the walls always being discoverable to some extent, especially by means of staining. As soon as they have been sufficiently weakened, action begins upon the starch grains. Their dissolution in this case is not by the translocation process, in which they gradually become

¹ Brown, H. T., and Morris, G. H. Researches on the germination of some of the Gramineæ, part 1, *Journal, Chemical Society [London]*, v. 57 (Transactions), p. 458-528, 1890.

smaller while still retaining their uniform shape, but by the corrosive action of a powerful digestive diastase. The grains become irregularly pitted and are rapidly absorbed.

The cells first affected are those in contact with the scutellum. According to Brown and Morris the first visible change in the appearance of the starch grains in the endosperm cells is coincident with the first appearance of starch in the cells of the scutellum, immediately back of the epithelial layer. After the first layer of endosperm cells has been broken through, the process gradually extends through the remainder of the endosperm. The action takes place along three lines: (1) It slowly proceeds directly into the mass of the starch endosperm; (2) it moves with more rapidity through the area immediately adjacent to the aleurone layer; and (3) it follows along the furrow at an even greater rate. The course of attack is thus directly opposite to that of the infiltration of starch. The cells last to receive deposits of starch are the regions of most rapid depletion. At the end of four or five days' slow germination, the path of affected tissue appears in longitudinal section as more or less of a crescent, the horns well advanced beneath the aleurone layer. Indeed, the crescent is already apparent in Plate II, figure 2, where germination was arrested at the end of the second day.

As germination advances, the tissues earlier affected become almost entirely liquefied and the diastatic and cytatic action proceeds to the reduction of the remaining endosperm areas. The last parts to yield are the dense deposits in the center of the flanks of the grain and especially those farthest from the scutellum. The epithelial layer undergoes some significant modification during this progressive starch solution. As previously noted, the cells first elongate slightly and certain changes take place in the protoplasm. Later there occurs (and more or less rhythmically reoccurs) a deposit which gathers in the outer ends of these cells. When the digestion is almost complete, the epithelial cells undergo a sudden elongation, attaining a length almost four times that which marked their former condition.

In the process of malting, the aleurone layer is not affected. It is found intact in brewers' grains even after they have endured the heating and strong diastatic action of the mash tub. In normal growth it is only when the plant has developed to the point of exhausting the starch endosperm that this layer begins to disintegrate and is absorbed by the plant.

CONVERSION OF THE ENDOSPERM.

The morphological changes in the endosperm are, of course, only the visible effects of the essential actions, which are enzymatic. The disintegration of the cell walls is a chemical transformation of cellulose to sugar and other compounds. The breaking down of the

starch is the result of the action of maltose-forming diastase. The disappearance of the plasmic network of the cells is due to its being peptonized by proteolytic enzymes and thus made soluble for absorption. Chemistry has made known the processes by which these changes are effected. It has found methods to increase the power of the grain to digest these various substances. It has invented ways of manipulation so as to secure the greatest efficiency of the enzymes present. It has not, however, shown any way of increasing the capacity of a grain to secrete enzymes, nor has it discovered any modification of structure that would lead to a greater economy in conversion.

It is only by a definite location of the sources of these energies that a working basis for improvement of the barley grain can be obtained. Not only must it be known which of the tissues are concerned in these activities, but the extent and nature of the action of each tissue must be understood. Upon this point there has been much divergence of opinion. The disagreement has been not only as to the parts of the grain concerned, but also as to whether or not the various enzymes are secreted by the same or by separate organs. Since there are three areas in dispute and three enzymes to be accounted for, the number of possible hypotheses has occasioned a very considerable confusion.

RÉSUMÉ OF THE CONCLUSIONS OF OTHER INVESTIGATORS.

Although the number of investigators who have been interested in one or several phases of this subject is great, a brief statement of their conclusions is necessary at this point.

Krabbe ¹ assigns all diastase secretion to the individual cells of the endosperm, based on his assertion that diastase can not pass from cell to cell.

Green ² finds in *Ricinus communis* a marked ability of the endosperm for self-digestion.

Hansteen ³ finds that the endosperms of *Zea mays* and *Hordeum vulgare* are capable of self-digestion when products of conversion are removed, that the aleurone does not supply the diastase, and that the scutellum is capable of vigorous corrosion of adjacent starch.

Pond,⁴ in an exhaustive chemical research, fails to discover any ability for self-digestion in the date.

¹ Krabbe, G. Untersuchungen über das Diastaseferment unter specieller Berücksichtigung seiner Wirkung auf Stärkekörner innerhalb Pflanze. Jahrbücher für Wissenschaftliche Botanik [Pringsheim], Bd. 21, Heft 4, p. 521-561, pl. 13-15, 1890.

² Green, J. R. On the germination of the seed of the castor-oil plant (*Ricinus communis*). (Abstract.) Proceedings, Royal Society, London, v. 47, no. 287, p. 146-147, 1890.

³ Hansteen, Barthold. Ueber die Ursachen der Entleerung der Reservestoffe aus Samen. Flora, Bd. 79, p. 419-429, 1894.

⁴ Pond, R. H. The incapacity of the date endosperm for self-digestion. Annals of Botany, v. 20, no. 77, p. 61-77, 1906.

Puriewitsch¹ concedes no more power to the aleurone layer than to the rest of the endosperm.

Torrey,² in studies of germinating maize, attributes the secretion of both cytase and diastase to the epithelial layer. He associates the enzym with the production of a definite granular substance in the epithelial cells the formation of which is coincident with the first attack upon the endosperm cells. Incidentally, he attributes the depleted layer of crushed cells, which is formed in the later stages of growth, to pressure and not to the absorption of the still growing endosperm by the expanding scutellum.

Van Tieghem³ finds, among many things less pertinent to this discussion, that the embryo of *Mirabilis jalapa* is capable of utilizing macerated endosperm as a nutritive substance.

Sachs⁴ considers, except for minor details, that the relation of embryo to endosperm is one of parasite to host.

Linz⁵ finds that the removal of the aleurone layer of corn makes little difference in the dissolution of the endosperm. He concludes that this layer is not secretive.

Grüss⁶ finds that the scutellum of barley is able to secrete abundant diastase and to nourish itself upon starch supplied in place of the endosperm.

Reed⁷ looks upon the epithelial layer as containing the only secreting cells in either *Zea mays* or *Phoenix dactylifera*, but concerns himself mostly with the changes in nuclear and plasmic conditions.

Brown and Escombe⁸ conclude that the scutellum of barley secretes diastase, but that the production of cytase occurs in the aleurone layer, but they do not find any power of secretion in a detached aleurone layer.

Green⁹ assigns the origin of cytase for the most part to the aleurone layer, but attributes the production of the greater part of the diastase to the scutellum.

Brown and Morris,¹⁰ in one of the most exhaustive investigations to which these questions have been subjected, find the scutellum of

¹ Puriewitsch, K. Physiologische Untersuchungen über die Entleerung der Reservestoffbehälter. Jahrbücher für Wissenschaftliche Botanik [Pringsheim], Bd. 31, Heft 1, p. 1-76, 1897.

² Torrey, J. C. Cytological changes accompanying the secretion of diastase. Bulletin, Torrey Botanical Club, v. 29, no. 7, p. 421-435, pl. 20, 1902.

³ Van Tieghem, P. E. L. Recherches physiologiques sur la germination. Annales des Sciences Naturelles, Botanique, s. 5, t. 17, p. 205-224, 1873.

⁴ Sachs, Julius von. Lectures on the Physiology of Plants. Tr. by H. Marshall Ward. Oxford, 1887, p. 373.

⁵ Linz, F. Beiträge zur Physiologie der Keimung von *Zea mays*. Jahrbücher für Wissenschaftliche Botanik [Pringsheim], Bd. 29, Heft 2, p. 318, 1896.

⁶ Grüss, J. Ueber die Secretion des Schildchens. Jahrbücher für Wissenschaftliche Botanik [Pringsheim], Bd. 30, Heft 4, p. 645-664, 1 fig., 1897.

⁷ Reed, H. S. Study of the enzym-secreting cells in the seedlings of *Zea mays* and *Phoenix dactylifera*. Annals of Botany, v. 18, no. 70, p. 267-287, pl. 20, 1901.

⁸ Brown, H. T., and Escombe, F. On the depletion of the endosperm of *Hordeum vulgare* during germination. Proceedings, Royal Society, London, v. 63, no. 389, p. 3-25, pl. 1, 1898.

⁹ Green, J. R. Soluble Ferments and Fermentation. Cambridge [England], 1899, p. 29, 93.

¹⁰ Brown, H. T., and Morris, G. H. Researches on the germination of some of the Gramineæ, part 1. Journal, Chemical Society [London], v. 57 (Transactions), p. 458-528, 1890.

barley capable of converting certain starches supplied in the place of its endosperm. They find that excised embryos are able to grow when the scutellum surface is grafted on endosperms in which life is extinct. They consider the endosperm no longer a vital tissue and claim that the aleurone layer does not secrete enzymes, assigning cytase, as well as diastase, to the scutellum.

Ling¹ supports Grüss, as opposed to Brown and Morris, regarding the extent of the dissolution of cell walls in conversion. The latter attribute the "mealiness" of malt to a marked dissolution of the cell walls. Grüss holds that the walls become merely transparent. Ling finds the walls present in all parts of the endosperm, although affected by cytase.

Vines,² while working with yeast and agarics, assumes that similar enzymes exist in other plants. He finds two classes of enzymes: (1) Those that peptonize and (2) those that peptolyse.

Beaven,³ while only incidental to the subject of his paper, remarks that the starch endosperm of barley is built up in centrifugal order and that its outer layer is easily broken down.

Gibbs,⁴ states that in the *Alsinoideæ* the greatly reduced endosperm is active only as an absorptive organ of the food material which is here stored in the perisperm.

Ellrodt⁵ finds that small-berried malts give a higher diastatic power per gram of original material than do large-berried ones.

Brown⁶ finds that the semipermeable membrane exercises a selective action, allowing water to enter the grain, but absolutely excluding most substances in aqueous solutions. The absorption is uniform in all parts of the grain.

SOURCE OF DIASTATIC FERMENTS.

On account of the fact that starch is the form in which most of the convertible material is stored, its digestion has received a great amount of attention. The process has been ascribed to three sources: (1) To a secretion of the endosperm itself; (2) to a secretion by the aleurone layer; and (3) to a secretion by the scutellum.

The theory of the self-digestion of the starch endosperm has been conspicuously championed by only two men, namely, Hansteen⁷

¹ Ling, A. Presence of cell walls in the endosperm of malts. (Abstract.) *Brewers' Journal* [New York], v. 29, no. 10, p. 440, 1905.

² Vines, S. H. Proteases of plants. *Annals of Botany*, v. 18, no. 70, p. 289-317, 1904.

³ Beaven, E. S. Varieties of barley. *Journal, Federated Institute of Brewing*, v. 8, no. 5, p. 542-600, 12 fig., 1902.

⁴ Gibbs, L. S. Notes on the development and structure of the seeds in *Alsinoideæ*. *Annals of Botany*, v. 21, no. 81, p. 25-55, 4 fig., pl. 5-6, 1907. Abstract in *Botanical Gazette*, v. 43, no. 5, p. 349-350, 1907.

⁵ Ellrodt, G. Unterschied des Diastasegehaltes von Malzen aus grosskörnigen und kleinkörnigen Gersten. *Wochenschrift für Brauerei*, Jahrg. 23, no. 20, p. 243-244, 1906; also in *Zeitschrift für Spiritusindustrie*, Jahrg. 29, no. 23, p. 209-210. Abstract in *American Brewers' Review*, v. 20, no. 7, p. 379, 1906.

⁶ Brown, A. J. On the existence of a semipermeable membrane inclosing the seeds of some of the *Gramineæ*. *Annals of Botany*, v. 21, no. 81, p. 79-87, 1907.

⁷ Hansteen, Barthold. Ueber die Ursachen der Entleerung der Reservestoffe aus Samen. *Flora*, Bd. 79, p. 419-429, 1894.

and, later, Pfeffer¹ in his review of Hansteen's work. The work of Hansteen is of some significance. He found that when the products of conversion were constantly removed, the endosperm was able to digest itself. His conclusion, however, that the endosperm is entirely capable of self-digestion is rather too sweeping, especially since he himself found a very active secretion of diastase in the scutellum, the existence of which function is hard to understand if it be superfluous. It is much more probable that the method used by Hansteen merely exaggerated the normal action of such diastase as would naturally be expected to be present in the endosperm of the ripened grain, for a certain minute amount of diastase is necessarily present in the cells of the endosperm to carry on the process of starch infiltration. This is, however, merely that phase of diastase needed for the translocation of the starch while the barley grain is forming. Indeed, according to the figures of Brenchley, the amount of diastase in the growing grain decreases as the grain approaches maturity. It is even reasonable to expect that not only would traces of this enzyme remain potentially functional in the endosperm of the ripened seed, but that the cells of this endosperm, once able to produce this ferment, would retain such ability to some degree, even in their less active condition. The effect of such small quantities of local diastase is not, however, to be confused with the vigorous attack that actually takes place in the process of germination. The conclusions of the writers are supported by those of many investigators, as above cited.

The theory that the aleurone layer is active in endosperm reduction has more in its favor than has that of the self-digestion of the endosperm. The aleurone layer is obviously high in vital energy. Its cells have the unmistakable aspect of active protoplasm. Their nuclei are large and present a sharp contrast to the distorted plasmic centers of the endosperm cells. The aspect of this layer during germination also lends much to the support of the hypothesis of its being functional. As previously noted, it is not digested with the endosperm, but persists until the endosperm is almost entirely absorbed. When germination is carried only to that point where the purposes of malting have been attained, the aleurone layer is still intact. As shown in figure 3, almost perfect sections of this tissue may be obtained from ordinary dried brewers' grains, in which the entire starch endosperm has been destroyed. In still further support of the idea, the disintegration in a newly germinating seed proceeds most rapidly directly adjacent to the aleurone layer. At certain stages this diastatic movement may be seen to have progressed until the thickest part of the endosperm is in a way surrounded with digested starch cells.

¹ Pfeffer, Wilhelm. Untersuchungen von Herrn Barthold Hansteen im botanischen Institut ausgeführt, über die Ursachen der Entleerung der Reservestoffe aus Samen. Berichte, Königlich Fachliche Gesellschaft der Wissenschaften, Leipzig. Mathematisch-physische Classe, Bd. 45, p. 421-428, 1893.

Tangl¹ has shown that the thickened cell walls in the endosperm of many seeds are provided with openings, so that the cell contents are not isolated but in intimate contact. This is true of the aleurone layer of barley, and the layer is in consequence more nearly a unit than might be supposed.

The accumulative importance of these and other facts has caused many authors to assert that the aleurone cells have a very important secretive function. The views of the individual experimenters who are inclined to this opinion are too numerous to discuss separately. The points of variance between them and the writers are few and

turn largely on the interpretation of specific phenomena.

These differences really center around a single fact. When the breaking down of the starch endosperm once commences next to the scutellum, it follows rapidly through the cells immediately beneath the aleurone layer. This point is frankly admitted, but is far from being a proof of aleurone activity. It has other interpretations more

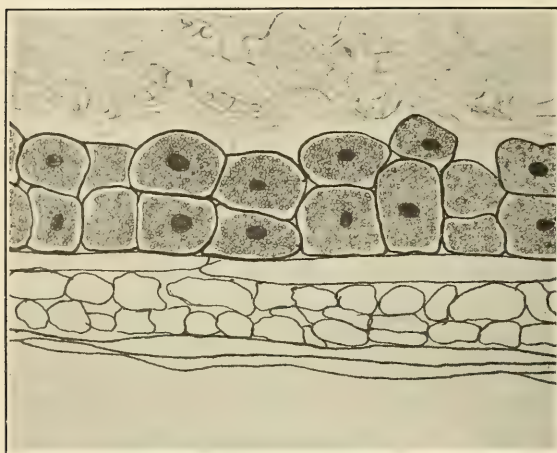


FIG. 3.—Section of piece of "brewers' grain," that is, of a barley grain that has passed through both the malting and the mashing processes. The aleurone layer remains unchanged. The cell contents are slightly shrunken by heating in the mash tub. The starch endosperm is fully depleted of its contents.

consistent with the general facts of germination. These cells adjacent to the aleurone layer are markedly different from those of the rest of the endosperm. They are younger. The starch endosperm is laid down and its cells filled in centrifugal order, so that its outer areas are the latest in formation and the latest in starch infiltration. They are also less gorged with starch. A grain of barley is not definitely limited in growth. In a way its growth is indeterminate, its development progressive until stopped by the act of ripening, a stage in which the failure of the supply of food is a marked factor. As may be seen in Plate III, the outer cells must from their very nature be younger and less filled with starch, their walls less desiccated, and their nuclei in a more nearly normal condition than those of the more thoroughly matured storage cells. A cross section

¹ Tangl, Eduard. Ueber offene Communicationen zwischen den Zellen des Endosperms einiger Samen. Jahrbücher für Wissenschaftliche Botanik [Pringsheim], Bd. 12, Heft 2, p. 170-189, pl. 4-6 [1880].

of a ripe barley grain treated with Millon's solution presents a strongly colored band just inside the aleurone layer and completely surrounding the rest of the endosperm, showing the relatively high proteid and low carbohydrate content of this region. The cell contents, therefore, are obviously not identical with those beneath.

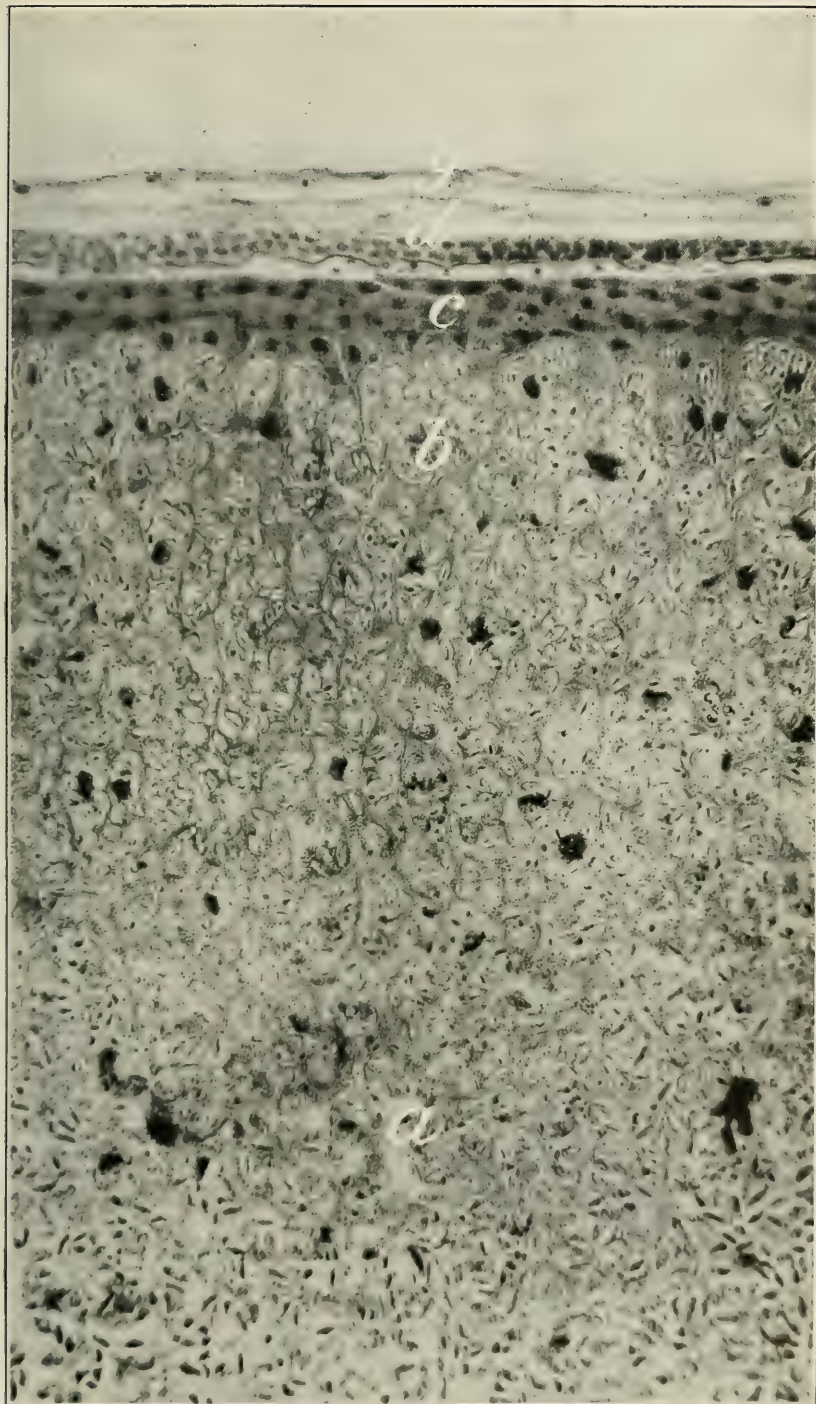
It is but reasonable to suppose that these young and loosely filled cells would be more easily broken down and that diastase, acting from the proximal end of the grain, even if distributed equally over the surface of the endosperm, would advance most rapidly along this area of least resistance. A strong point against the aleurone theory of digestion is the fact that the cells of the endosperm first affected are those next to the scutellum, as shown in Plate IV. If the aleurone layer is active, why should not this take place uniformly in those cells lying directly beneath that layer? Sections made through grains germinated at high temperatures show the proximal end of the endosperm to be in complete solution, while the cells next to the aleurone layer toward the distal end of the grain are entirely unaffected. This can not be due to a lack of water, for water can be shown to pass readily through the walls of all parts of the grain. One or two authors have attempted to ascribe this condition to a certain inexplicable stimulus which proceeds from the growing plantlet and passes through the connected plasma of the aleurone cells, inciting them to successive action. Such theory fails to explain why the movement advances much more rapidly along the furrow than elsewhere. The cells in this region are for the most part dead tissue and would be incapable of aiding the aleurone layer or of carrying any stimulus. However, since the region of the furrow contains the conducting tissue during the development of the grain and since it leads past the scutellum, it is readily seen that it could be still instrumental in carrying secretions from that source, although incapable of conveying stimuli.

A more plausible defense of the theory of aleurone secretion has been advanced in the statement that the enzymes are able to work only when the products of their conversion are removed, and that the scutellum as an absorbing organ is responsible for the fact that the action commences adjacent to it and can not proceed elsewhere, except as the process of removal becomes effective. This theory is not borne out by observations, in that the lack of a means of removal would not prevent the preliminary stages of dissolution from taking place at all points in contact with the aleurone layer. No such effect occurs. Moreover, the percentage of maltose necessary to the inhibition of diastatic action is very high, certainly not less than 30 per cent. That this percentage is seldom reached is shown by the fact that the cells first acted upon while in a partial state of conversion pass on to the point of complete dissolution, even though they

are gorged not only with their own products of conversion but with those of the cells lying beyond them.

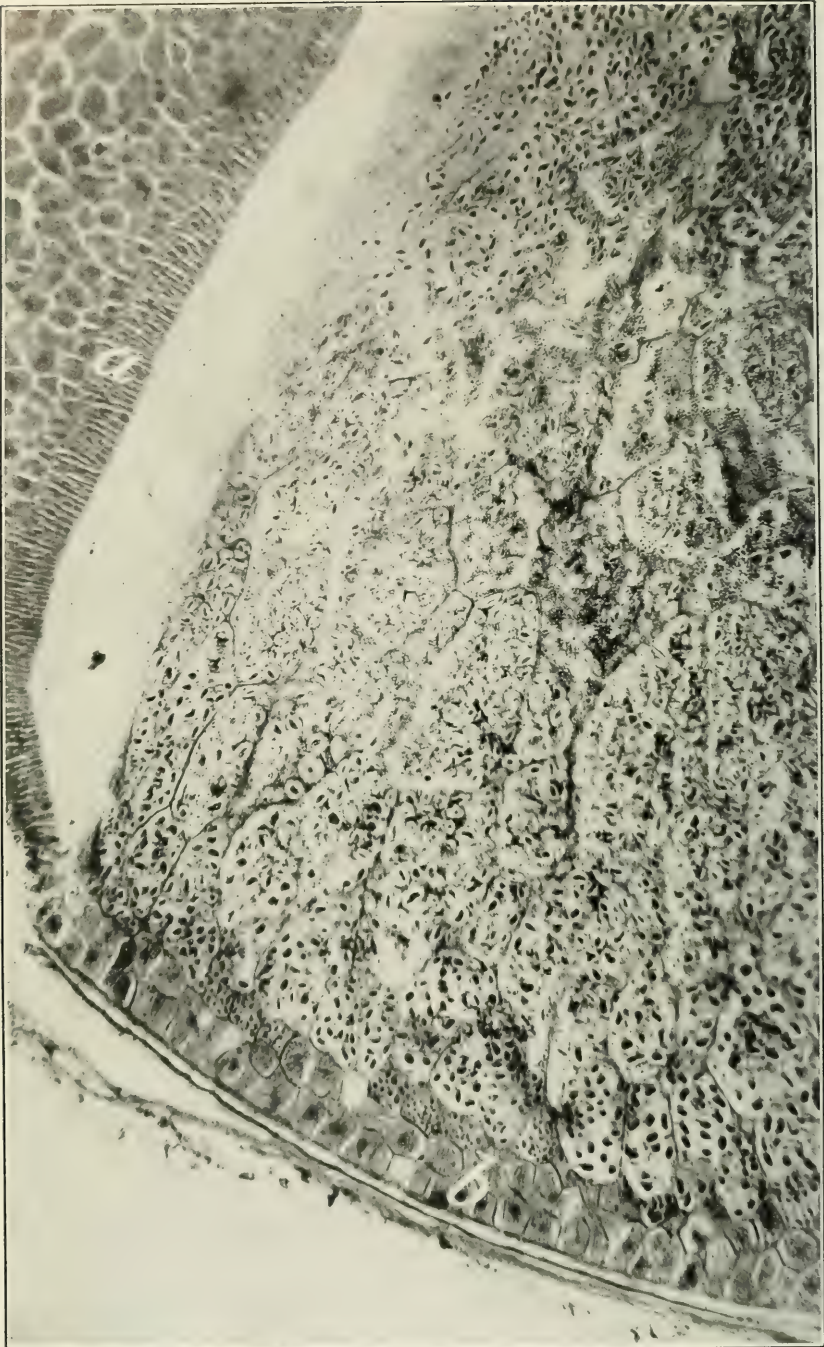
As must be evident from the writers' opposition to the theories of self-digestion and of aleurone activity, their investigations have been overwhelmingly in favor of placing the entire function of diastase secretion during germination upon the scutellum. Morphological examinations have been made of thousands of barley grains at all stages of germination. These have been repeated with a large number of varieties and types of barleys grown under varying conditions in America and of seed imported from all parts of the world. In all cases, the dissolution of the endosperm is effected in the same manner. The corrosion commences with the parts directly in contact with the scutellum. The action begins as quickly in front of the cells in the center of the scutellum as it does in those next to its periphery and therefore in juxtaposition to the aleurone layer. All later action is such as would occur if the scutellum were the only source of diastase. A grain from which the aleurone layer is removed is converted in the usual manner. Moreover, the very appearance of the scutellum is convincing. On its surface is the epithelial layer, which is typically glandular. There are in plant growth no tissues that closely resemble specialized secreting tissues, and seldom is there a more unmistakable development of this than the epithelial layer, as shown in Plate V, figure 1.

Most investigators have recognized the secreting power of the scutellum; indeed, none have denied such function, even when attributing to it only a subsidiary activity. Numerous experiments have been made in the past and many of them repeated by the writers. A grain from which the embryo is removed will not show any tendency to germination, even though all external conditions, such as light, heat, and moisture be made favorable and ample provision for the removal of conversion products be made. On the other hand, and under proper artificial conditions, the scutellum is able to support itself and to supply food for the growth of the plumule and radicle independent of the endosperm. Morris and Brown, Hansteen, Pfeffer, and numerous others have shown the ability of the embryo (with the scutellum) to digest the starch supplied to it. This has been demonstrated in numerous ways. The starch has been furnished in the form of macerated endosperm and in the form of a mixture of starch and plaster. In every case, the scutellum was able to corrode the material supplied and to promote a considerable growth in the plantlet. The embryo is also able to utilize an endosperm which is entirely without living protoplasm. An excised embryo from a healthy, vital grain can be grafted upon a dead endosperm with perfect success. Such endosperm may be prepared in any way desired, even by prolonged soaking in absolute alcohol; that is to say, after



PHOTOMICROGRAPH OF A LONGITUDINAL SECTION OF A PORTION OF A BARLEY GRAIN
IN THE EMBRYONIC STATE.

a, Inner area of the endosperm, with starch grains; *b*, outer and younger area just forming, with few starch grains and large nuclei; *c*, aleurone layer; *d*, integuments and pericarp; *g*, fragments of glumes.



PHOTOMICROGRAPH OF A PART OF THE SCUTELLUM AND ENDOSPERM OF A GERMINATING BARLEY GRAIN.

The initial stage of germination is shown. Enzymatic action has begun in front of the epithelial layer (*a*), but not next the aleurone (*b*).

a submersion for several months in this killing fluid a living embryo is able to effect the usual processes of conversion.

That the functions of the scutellum are localized in the epithelial layer is readily shown by experiment. The removal of this layer immediately results in an absolute loss of the scutellum's power of digestion. It is so fully incapacitated that no visible corrosion is effected upon a contact surface of starch, when previously such effect was very marked. An epithelial layer, even when not connected with the embryo, seems able to accomplish a slight change, even though no provision for the removal of the products of conversion is made.

The exact way in which the epithelial layer produces diastase is not known. The change in the plasma, the elongation of the cells, and the peculiar granular deposit that accumulates at their outer ends are all probably connected with the exercise of this function. Indeed, Torrey has gone so far as to assert that this is a deposit of actual enzymatic substance. He asserts that it appears, gathers at the outer end of the cell, and then passes into the endosperm, that the cell stays clear for some time, and that the same phenomena are then repeated. The writers have not verified this statement beyond noting that the deposit varied greatly in individual grains which were killed at different stages of germination. Sometimes the entire end of the cell was clouded and the outer end heavily charged with a coarse granular deposit, and at other times it was entirely free.

LOCATION OF DIASTASE SECRETION.

There are two diastases present in the barley grain: One of translocation, capable of only weak action; and one of digestion, capable of powerful corrosion.

The endosperm is incapable of self-digestion other than the slight action of the diastase of translocation.

The aleurone layer is made up of highly vital cells, which persist until the starch endosperm has been almost completely absorbed.

The most rapid starch conversion is next to this layer.

These facts are not sufficient to ascribe any secretive function to the aleurone layer, the rapid dissolution next to this tissue being due to the fact that from their nature the adjacent cells are easier to break down than the ones in the central part of the endosperm. An even more rapid corrosion follows the furrow, although it is largely composed of inactive and dead cells. No corrosion is to be found next to the aleurone layer except as the changes move outward from the scutellum. The absence of means to remove the products of conversion taking place at the distal end should not prevent the first stage of conversion taking place if the aleurone layer were an active enzymatic organ.

That the scutellum is active in enzyme secretion is shown by the fact that the first changes occur in the layer of endosperm in contact

with it, and all later progress in conversion is made from it toward the distal end of the grain.

The embryo is able to feed upon starch substituted for its normal endosperm. Living embryos are able to grow when grafted on endosperms which have been previously killed.

The function of enzym secretion in germination is localized in the epithelial layer of the scutellum. Embryos from which this layer has been removed are unable to convert starch.

SOURCE OF CYTATIC AND PROTEOLYTIC FERMENTS.

The location of the secretion of diastase is not the only point in the physiology of the grain upon which investigators have differed. Some authorities who have placed this function in the scutellum have ascribed the formation of cytase and of the proteolytic enzyme to other sources.

With cytase, if the conclusions of the writers be correct, the question is soon settled. If starch conversion starts next to the embryo and moves toward the distal end of the grain, cytase must also be a product of the epithelial layer. The breaking down of the cell walls must always precede the action of diastase. The diastase of digestion seems to be unable to pass readily through unmodified cell walls, and most certainly the cell walls are not affected much beyond the depleted zone. These two enzymes, then, must of necessity not only be associated in the changes which occur in the endosperm, but must proceed from a common source.

The proteolytic ferments would appear from analogy to present no differences from the other two. Proteolytic action certainly does not occur in any part of the endosperm not yet reached by cytase and diastase. If the proteolytic ferments are secreted by the aleurone layer they do not become operative until the cytase has moved forward from the scutellum and has broken down the cell walls. This lack of plausibility is not proof, but, on the other hand, there is no reason for thinking that there is more than the single source of enzymatic secretion. In one or two other grasses any other origin than the scutellum is apparently impossible, because the aleurone layer is digested almost as readily as the starch endosperm. In these cases, at least, the secretion must be a product of the scutellum, and in barley every indication short of absolute proof insists on the same conclusion. In the opinion of the writers, the scutellum as a feeding organ is endowed with all the functions of digestion, being able to utilize all foods occurring in its natural storehouse, the endosperm.

FUNCTION OF THE ALEURONE LAYER.

These conclusions leave unexplained one very evident fact. The aleurone layer is obviously a vital tissue. Its cells are in no way similar to those of the starch endosperm beneath it. This marked

difference can not be without a purpose, and fortunately this purpose is easily explained without the necessity of having recourse to any theory of secretion. The aleurone layer undoubtedly exercises a strong protective function. In rainy weather, fungi are invariably to be found investing the barley grain and feeding upon the feebly active cells of its envelopes. Their hyphæ often run through all the investing layers of the seed without being able to penetrate the aleurone layer. Whether or not it be the vital resistance of its protoplasm, the mere mechanical obstacle of its heavily cuticularized walls, or both, this tissue is an effective barrier to the inroads of molds and bacteria. The fact that such protection is of absolute necessity is readily appreciated. Within the endosperm is stored the food upon which the future development of the embryo is absolutely dependent. Even the perpetuation of the species rests upon the proper conservation of this reserve food material. This mass of readily assimilated compounds is an ideal food for all sorts of saprophytic and parasitic organisms. It is therefore not surprising to find built around this material a specialized tissue with a highly protective function.

The aleurone layer serves a second purpose, but one which alone would hardly justify its existence, in that it appears to be more opportune than essential. When the plant is first establishing itself in the soil, it utilizes the starch endosperm, a material rich in carbohydrates, which seems to meet all the requirements of early growth. When once its green leaves are exposed, however, photosynthesis is able to supply all its needs for starch. With nitrogenous food material the problem is more difficult. A considerable extension of feeding surface in the roots is necessary before such material can be procured in any quantity. The starch endosperm contains an extremely limited amount of nitrogenous matter and that stored in the embryonic tissues is soon exhausted. The breaking down of the aleurone layer and the utilization of its highly nitrogenous cell contents comes at the critical period in the life of the plantlet when this material is of especial value. This may account for the extra thickness of this layer in certain genera of grasses, of which *Hordeum* is one of the most notable examples.

GREATER DIASTATIC POWER OF SMALL-BERRIED AND OF HIGH-NITROGEN BARLEYS.

It is interesting to note that the theory of scutellar secretion conforms nicely to an apparently satisfying explanation of a widely recognized fact in the utilization of barley malt. Distillers have long known that their requirements are best met by a malt of high diastatic power and that small-berried barleys of high nitrogen content are best adapted to produce such malt. With those brewers who are producing a beer in the manufacture of which malt adjuncts, such

as corn grits or brewers' rice, are used in conjunction with malt, the same type of malt is popular, although an extreme development of diastase is not here demanded, because the additional amount of starch to be converted is less.

The explanation of the greater enzymatic power of small-berried barleys seems simple. The diastase-secreting surface is confined to the epithelial layer. The proportion of epithelial surface to volume of endosperm should also represent the ratio of diastase to starch. For the purpose of illustration, the shape of the barley grain may be considered as a sphere, while the curve of the scutellum may be taken to represent that of a second sphere partly included in the first. If the size of the grain is made greater, its volume is increased much more rapidly than the area of the surfaces of the spheres, according to well-known laws of geometry. That is to say, for any increase in the size of the grain the increase in the area of the surface of the scutellum is much less proportionately than the increase in the volume of either the embryo or the endosperm; and, conversely, as a grain decreases in size the epithelial surface decreases much less proportionately than the bulk of its endosperm. It is therefore but natural that the diastase production in a small grain should be relatively greater than in a large one and often greatly in excess of the needs for conversion.

The relation of diastatic power to nitrogen content is a slightly more complex problem. In general, barleys high in nitrogen are also high in enzymatic power. The case varies somewhat with conditions. In the small-berried barley the same facts apply as in the ratio of scutellar surface to endosperm. The aleurone layer is one of the great sources of nitrogen in the barley grain. This layer is almost invariably three cells deep. If the grain be very small, the two or three layers of cells completely encircling the starch endosperm form a very considerable part of the grain. Since they are high in nitrogen, this element tends to represent a higher and higher percentage of the total as the diameter of the grain is progressively reduced. In a very small grain the percentage of nitrogen is therefore likely to be high, even though the starch endosperm be ever so mealy, the deciding factor being, of course, the great proportion of the aleurone layer.

There is, however, among the 2-rowed barleys a different situation, in that climate and culture assume a greater importance. Barley-growing areas are often conspicuous for their production of high-nitrogen barleys. Indeed, the crops of any section vary in this respect from year to year. It is almost invariably the case that these high-nitrogen crops are also high in diastatic power, often possessing an enzymatic potency almost equal to that of the small-berried sorts. In these cases, also, the explanation is found in the ratio of the

secreting surface to the starch endosperm. The growth of the grain in such cases is not normal. The stimulation of the vegetative growth has been greater than the later starch infiltration could balance. The embryo and general structure of the grain have attained large proportions, but the starch infiltration has been incomplete. A normally grown and matured grain of 2-rowed barley possesses a highly developed starch endosperm. Although this endosperm is the first part of the grain to commence active growth, it is the last to be completed in the process of ripening. If any feature of climate or culture interferes with the process of starch deposition, the grain remains high in nitrogen content. This excess is due more to the absence of starch than to the presence of nitrogen. There is, then, a large scutellum without the corresponding bulk of starch. The enzymatic secretions intended for the conversion of a large endosperm are more than sufficient for the reduced starch content, and both diastatic power and nitrogen content are higher than usual.

In substantiation of this view, measurements were made upon two samples of Princess barley. These were grown at Huntley, Mont., in 1911. One sample was produced upon dry land, while the second came from a neighboring plat which had been irrigated. The thousand-berry weight of the irrigated barley was 45.5 grams, while that from the dry-land plat was only 30.1 grams. The scutellums in either case were quite uniform. Those from the irrigated sample averaged a little less than 2.6 millimeters in diameter, while those from the dry-land sample fell to 2.4 millimeters. The scutellar areas were, then, 5 square millimeters for the one and 4.3 square millimeters for the other. That is to say, under such conditions that the grain did not develop to its fullest extent the scutellar area was reduced approximately 14 per cent. However, at the same time, the total reduction of the grain was 33 per cent. As the hulls are more or less a constant factor, the actual reduction of endosperm was probably far in excess of 33 per cent. This case is but a slight exaggeration of the conditions of incomplete development that usually obtain over a considerable part of the upper Mississippi Valley. The scutellum of 2-rowed barleys in this section is, for the most part, likely to be relatively a greater part of the grain than is normally the case in this group. Such barleys grown in this section are likely to show a much greater converting power than has been suspected.

EFFICIENCY OF CONVERSION.

If the conclusions of the writers be correct, the application of these facts to barley production and utilization is of much importance. If the secretion of enzymes takes place in the epithelial layer, the gross morphology of the grain must govern its behavior in germination, including that modified form of germination known as

malting. The perfection with which an endosperm undergoes digestion depends upon the amount of diastase present and upon the location of the endosperm with reference to the diastatic source. It is the aim of malting to carry the disintegration of the endosperm only to that point where cytatic action has been completed and where diastase formation has reached a large total which has been distributed through the grain. Very little starch conversion is desired in the process of malting. Indeed, none is desired, since the sugars thus produced are in part absorbed by the growing plant and not only lost but changed into undesirable products. The low temperatures at which the grain is malted are for the purpose of

restraining this conversion. Every effort is made to prevent the absorption by the plantlet of the contents of the proximal region of the endosperm before the enzymatic secretions have reached its distal end and have permeated the dense starch areas in the upper flanks of the grain. When this is attained the embryo is killed to prevent any further absorption. The object of malting is, therefore, to subject all parts of the endosperm to



FIG. 4.—Two grains of a Bohemian barley; a broadly oval-shaped grain well adapted to malting with little loss.

the initial effects of enzymes with as little loss as possible. The ideal condition would be a simultaneous attack upon every cell wall and every grain of starch. This is impossible with the source of the action localized at one extremity of the grain. However, the coordination of the scutellum with the endosperm has a marked effect.

The shape of the grain with reference to the size and shape of the associated embryo has in more than one variety been the deciding factor between a good and a poor malting barley. If the great mass of the starch be near the embryo, as in the short, thick grain shown in figure 4, the disintegration of the endosperm is readily and uniformly accomplished, but if it be distant, as in long, slender grains, the complete modification of the endosperm mass can not be accom-

plished without great loss. That is, the more nearly a grain approaches a sphere in shape, the less need be the loss in malting; and the greater the ratio of the longer axis of the grain to the shorter the more difficult becomes the malting. In extreme types, such as the Chinese barley shown in figure 5, efficient malting is impossible. If the process is stopped in a reasonable time, there remains an unaffected portion at the distal extremity, whereas if germination is continued until this portion becomes softened, the entire proximal end will have been utilized by the plant. The 2-rowed barleys from Smyrna are less marked examples of the same defect. They are almost ideal in character, considered from the standpoint of high extract alone, except for their unfortunately long grain. The shape of the grain makes this barley difficult to malt, and the extract is probably measurably less than would be the case if the same seed contents were differently arranged. Barleys with long grains and with pointed ends are to be avoided for malting purposes, if yield of extract be even of secondary interest.

The amount of diastase present in any type of barley must depend upon the area and vigor of the secreting surface. If the secreting surface be large, enzymatic action should be ample. As previously pointed out, the proportion of the secreting surface must, by the laws of geometry, increase as the size of the berry decreases. Thus, in small-berried barleys the diastatic power will be high, regardless of the nature of its endosperm. If, in addition, the endosperm be dwarfed by a lack of normal starch infiltration, resulting in a high-nitrogen grain even for its class, the excess of diastase becomes still greater and results in a malt adapted to the use of distillers. The question of increasing this function in such barleys thus seems superfluous. Nevertheless, as will be shown later, even in the case of the

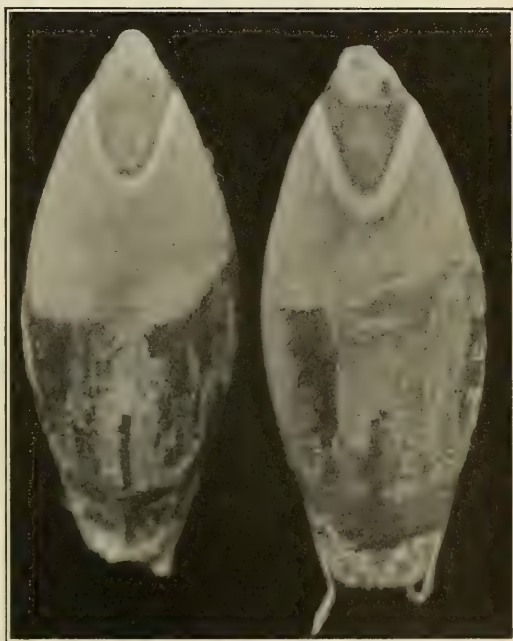


FIG. 5.—Two grains of a Chinese barley, a spindle-shaped grain very difficult to malt.

Manchuria and Oderbrucker barleys, the nature of the secreting surface is of importance.

As the size of the grain increases, the efficiency of the converting power becomes a vital question. The relative decrease of the surface of the epithelial layer, together with the increased percentage of starch in the endosperm, makes an adequate amount of diastase of the utmost importance, especially if it be desired to convert starch in addition to that already in the endosperm. To have the largest contact area, the embryo must completely occupy the proximal end of the grain, and the grain itself must be as broadly oval as possible in order to provide for this maximum expansion. When these conditions are fulfilled, the resulting scutellum is a broad organ, reaching well over the shoulders of the grain and resting in a shallow, saucer-shaped depression in the endosperm.

To test the accuracy of this conclusion, examinations have been made of almost every commercial barley in the world. Several of the types found are shown in Plate V, figure 2, and in Plates VI and VII. In all cases where the grains were large, the varieties recognized as superior malting barleys each possessed a scutellum of the above type. On the other hand, barleys known to be inferior for malting were invariably characterized by the other extreme of scutellum, that is, by one which did not reach out over the shoulder of the grain. Usually a slight compensation for defective breadth of scutellum was offered by its being deeply sunken in the endosperm. This addition of surface was slight, as it must be readily realized that the increase of the few degrees of surface secured could not offset the very considerable decrease of diameter. The comparative area of the spherical surface of the large scutellum is actually greater than that of the slightly elongated, small one, so that the broad, flat type of necessity presents the greater secreting surface.

There seems to be a more or less definite correlation between the shape of the scutellum and the form of the grain. A long, pointed grain is almost invariably accompanied by a narrow, deeply sunken scutellum. Of course, the fact that the proximal end was reduced would of necessity cause a like reduction of the embryo. However, even more than such inevitable restriction usually occurs. In such grains the borders of the scutellum in a moistened grain do not ordinarily protrude at the points of contact with the aleurone layer, but are even more narrow than the available space requires. In a very few types, as the Smyrna, this is not wholly true.

While the most important factor of enzymatic production is thus seen to be the surface area of the secreting organ, there is still an additional element. There may be a difference in the quality of the secreting tissue. In other words, the epithelial layer varies with reference to the character of its cells. In some barleys it is made up of short, broad cells; in others the units are long and narrow. (See

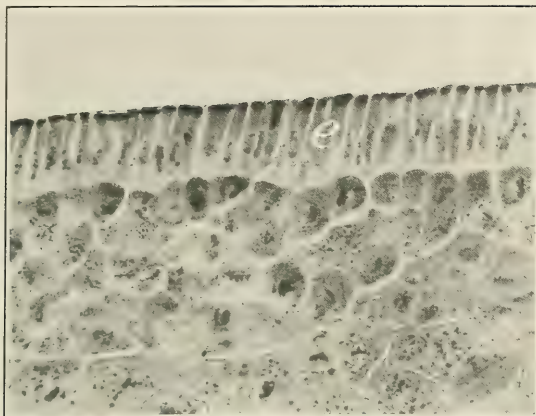


FIG. 1.—PHOTOMICROGRAPH OF THE SCUTELLUM OF A GERMINATING GRAIN WITH ITS EPITHELIAL LAYER.

In the ends of the cells of the epithelial layer (*e*) is to be seen the black deposit, thought by Torrey to be diastase. In front of the epithelial layer the endosperm has been reduced to a milky solution, while the scutellar cells back of it are obviously highly vital.



FIG. 2.—TWO GRAINS OF FINNISH BARLEY.

A grain of undesirable spindle shape and a small, insufficient scutellum.



FIG. 1.—TWO GRAINS OF PLUMAGE BARLEY.

This barley was originated by E. S. Beaven, Warminster, England. It is a grain of desirable oval shape and has a broad, ample scutellum, a combination of characters adapted to secure the highest percentage of malt extract.

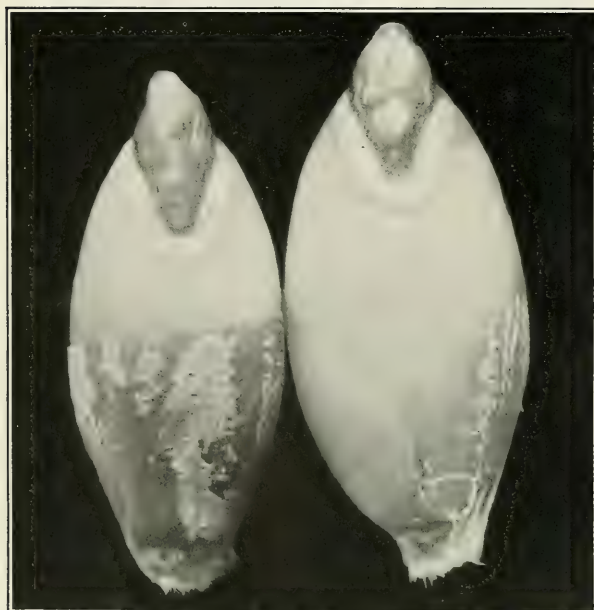


FIG. 2.—TWO GRAINS OF AN ASIATIC BARLEY.

A grain of fairly oval shape, but with a small, insufficient scutellum.

fig. 6.) Given the same area in contact with the endosperm, the epithelial layer composed of long cells will have a much greater cubical content. Also, if the cells be narrower, their total number will be greater in a given area. If Torrey's conclusion that the nucleus is the final organ to which secretion is due is correct, this increase in the number of cells and in the consequent number of nuclei is an actual increase in secreting power. In any case, it is reasonable to assume that a greater number of cells with a greater plasmic content is more efficient than a smaller number of cells with a smaller plasmic content. The existence of this type of epithelial layer in the most prized malting barleys gives corroboration to this belief. The long, narrow cell prevails in the better sorts, but becomes less prominent as the quality decreases.

An ideal grain of barley, then, is one possessing a relatively short longitudinal and a correspondingly long transverse diameter, with both the distal and proximal ends broadly oval. It contains an embryo with a large scutellum reaching over the edges of the endosperm and an epithelial layer composed of long, narrow cells.

An inferior grain of barley is elongated and is pointed at both ends. It contains an embryo with a narrow scutellum the epithelial layer of which is made up of short, broad cells.

A barley having the most perfect construction for the production of enzymes may still fall short of its highest efficiency. The size and the quality of the secreting surface are the structural factors of potential energy, but they are limited by a third element, namely, condition. If they are not in the highest state of vital energy, their maximum efficiency will not be realized; and, furthermore, this vital energy must be in a certain state of activity not entirely understood and difficult to define, which may be designated, for want of a better term, as "potency." For example, at the time of the maturity of the

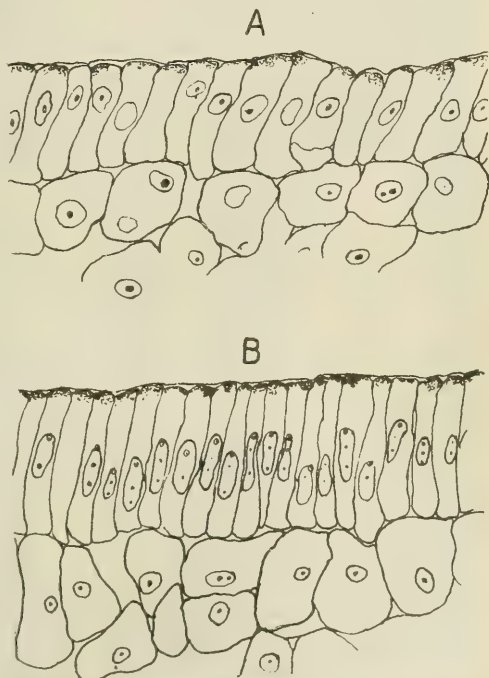


FIG. 6. — Two types of epithelial layers: *A*, An inferior epithelial layer of short, broad cells; *B*, an efficient epithelial layer of long, narrow cells. (Camera lucida drawings of actual specimens.)

grain the protoplasm of the cells of the embryo is active and possessed of all the vitality of newly formed tissue, yet barley germinates very imperfectly at this time. The epithelial layer will attack the endosperm, even under the most favorable conditions of moisture, temperature, etc., only in a weak, erratic manner. The cells do not seem ready to exert their full force. In fact, it is only after a certain period of rest that the grain displays its full germinative potency and

becomes thoroughly responsive to germinative influences.

It has been noticed that the "sweating" process in the curing of barley is closely connected with this change in the internal energy of the grain. If grain be sweated in the stack, both the percentage and the vigor of its germination are increased to the maximum. Any other method of treatment after cutting is inferior, the changes being brought about under more adverse conditions. If the curing process takes place in the shock, it occurs irregularly and imperfectly and at the same time the grain is exposed to the weather. If it occurs in the bin, there is danger of overheating and consequent

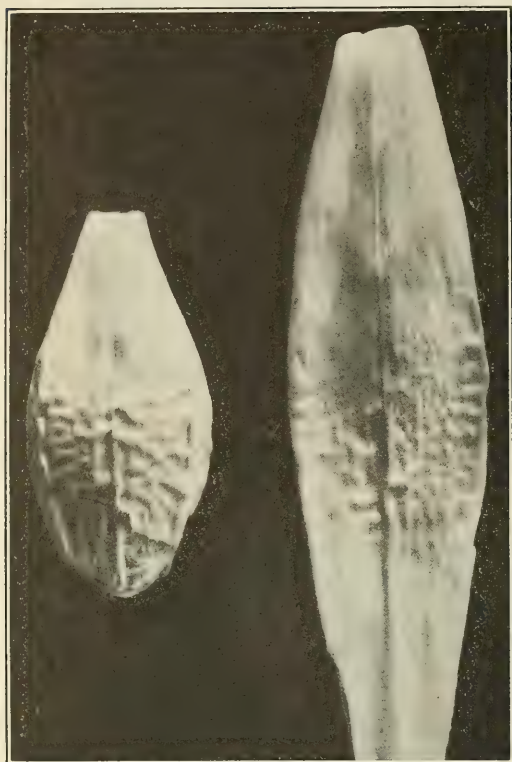


FIG. 7.—Two grains of barley from a commercial sample, showing the extremes of variation to be found in barleys as grown at present in this country. Economical malting of a barley that contains any considerable percentage of such extreme shapes is impossible.

damage. The vigor of germination may be affected in this way even when there is no visible indication that deterioration has occurred. Of course the injury is likely to be more serious and even to make the use of the barley for malting purposes impossible.

These various factors of efficiency in the conversion of the barley grain, when applied to commercial malting operations, presuppose pedigreed barley. The efficiency of the ordinary market barley may be increased by careful culture, but it will never become really superior. The commercial varieties as they are sold in the markets are composed of many subvarieties (fig. 7). The Manchuria, the Oder-

brucker, and the Bay Brewing usually represent mere group names for general types of barley that are in no sense pure varieties. From each of them many widely different strains may be isolated. Some of these are early and some late, some are large berried and some small berried, some germinate quickly and some slowly. When such a mixture is malted, it is obvious that the malt must be lacking in uniformity. Some of the acrospires will be protruding and some barely started. Some of the grain will be overmalted and some undermalted. The percentage of extract must necessarily be much lower than might be procured from any one element of the mixture if the elements were separated.

The purifying of the common commercial varieties will result in a more uniform malt and a higher percentage of extract. Any further step toward a greater efficiency must fall back on the use of 2-rowed barley. For botanical reasons, a 6-rowed variety can never be made as uniform in the size and character of its grain as a 2-rowed. Certain usages in manufacturing not germane to this discussion may demand 6-rowed varieties, but, considered only from the standpoint of yield of extract, the 2-rowed sorts will always remain superior.

AMERICAN BARLEYS.

The application of the factors of endosperm conversion to American conditions is more simple than the diversity of production and demand might indicate. There are in the United States but three main barley-producing areas, the Pacific coast region, the Rocky Mountain irrigated sections, and the upper Mississippi Valley. In the three Western States, California, Oregon, and Washington, the climatic conditions are such that a barley peculiar to that section is produced. The dry, sunny ripening season results in a starchy grain of very low nitrogen content. This is true regardless of variety, though variety exercises a noticeable influence. As a whole, all varieties of this district are large grained. Even the common California barley, which is 6-rowed, possesses a grain of greater size than many of the 2-rowed varieties grown elsewhere. Indeed, even when grown in the Plains States it maintains its relatively high thousand-berry weight. Regardless of variety, the problem in the West is, therefore, to secure all the enzymatic development possible. The large amount of starch endosperm to be converted makes this desirable. Although any grain possesses enough diastatic power for the conversion of its own endosperm, for malting purposes an excess is useful even though it is not used for the conversion of additional starch. A more uniform malt can be made by holding back a powerful diastase that evenly floods the endosperm than by the action of a lesser quantity that must pass from cell to cell in a more fitful attack.

In the Rocky Mountain area, the starch formation is usually not so pronounced as nearer the coast. The secreting surfaces in most vari-

eties are satisfactory, even to the extent of supplying surplus malting energy.

The upper Mississippi Valley is a section of high-nitrogen barleys. For the most part the crop is of the small-berried 6-rowed Manchuria or Oderbrucker type. It is in this region that the greatest divergence of demand is felt. A majority of the malt consumers of the Northwest use malt adjuncts. Indeed, this custom may be said for all intents and purposes to be universal. They demand a barley of high diastatic power, so as to convert the various forms of grits added to the normal starch endosperm of the malt. This demand is not in conflict with the facts of scutellar secretion. The diastatic power of small-berried barleys is simply a matter of the shape and size of the scutellum. If this power can be increased in any barley, it can also be increased in Manchuria barley. A greater diastatic power would allow the use of a grain with a larger starch endosperm and would result in a higher percentage of extract without any loss in the desired excess of diastatic energy. The Manchuria as it is sold on the Chicago markets does vary considerably in this respect. The comparison of a good-malting Manchuria with a poor-malting Manchuria barley showed that in the good barley 83 per cent of the grains had a scutellum of desirable type, while in the poor barley only 16 per cent were of this type.

Two-rowed barleys grown in the upper Mississippi Valley are likely to be much more vigorous in enzymatic action than has been thought. From all the tests of the writers these barleys are shown to be of rather high nitrogen content. This means that the grain possesses an embryo stimulated to a growth such as would provide diastase for an exceptionally large endosperm. It also means that such an endosperm has not been developed, that much of the space in the starch cells is occupied by proteid contents, and that these cells will be comparatively easily broken down. Such being the case, it is more than probable that 2-rowed barleys grown in Wisconsin, Minnesota, Iowa, and the Dakotas will be found to be able to convert a considerable amount of added starch, if handled so as to develop their greatest efficiency.

MODIFICATIONS POSSIBLE BY CULTURE.

The scope of this bulletin does not admit of a full consideration of one subject intimately connected with barley structure, namely, the great changes produced by different methods of cultivation, for a full understanding of this subject would involve a discussion of principles of plant breeding and methods of barley farming too extensive to be herein included. But at least a brief statement of the correlation between the two is necessary at this point. It may be said in general that efforts to obtain by means of culture barleys of high enzymatic



FIG. 1.—TWO GRAINS OF AN ABYSSINIAN BARLEY.

This is a fairly well-proportioned grain with a fairly ample scutellum.



FIG. 2.—TWO GRAINS OF STANDWELL BARLEY.

The broad scutellum and the thick oval grain are adapted to secure a very high percentage of malt extract.



TWO SAMPLES OF PEDIGREED PRIMUS BARLEY GROWN THE SAME SEASON AT DIFFERENT POINTS IN THE UNITED STATES, SHOWING THE EFFECT OF SOIL AND CLIMATE ON THE SCUTELLUM.

In A the scutellum has degenerated, while in B it has remained of desirable shape.

power will be most likely to succeed if they are directed separately toward the four factors of efficiency, viz: (1) The shape of the grain, (2) the size of the scutellum, (3) the quality of the epithelial layer, and (4) the vital energy of the mature grain. All of these factors but the last are varietal characters. Fortunately, varieties of extreme inferiority are for the most part already eliminated because of their low yield. The only decidedly inferior ones often met with in actual cultivation in America are certain Russian barleys with long, thin grains, a few winter varieties of similar character, and hooded sorts that probably are abnormal in form because of the lack of the functional activity of the beard.

Among the varieties the normal qualities of which are desirable, it not infrequently happens that the actual product is far from perfect; for ideal shape is largely a matter of development, even in a variety in which such is possible, and not only a matter of development but of ideal development. If the conditions of soil and cultivation are satisfactory and the climate such as will allow a correct maturation, the whole crop will consist of good, uniform seed. If these conditions do not prevail, a faulty product will result. Soil and cultivation are under the control of the farmer, at least to a limited extent, and it is the neglect of these limited influences that is responsible for much of the inferior barley produced. The English farmer has a saying that "barley is a gentleman;" that is to say, if the ideals of structure in this grain and the delicately balanced physiological functions based on structure are to be secured, barley, above all other crops, can not be treated with indifference.

The more general influences affecting adversely the cultivation of the best grades of barley by the American farmer may be briefly outlined as follows: (1) Overstimulation of purely vegetative growth by improper soil and fertilization, (2) unfavorable climatic conditions during the growing period, the factor which explains why the southern limit of good barley cultivation in the Mississippi Valley is so far north, and (3) improper methods of harvesting and curing the barley crop.

It is probable that the part of the barley grain most quickly and extensively modified by changes in the conditions of cultivation is that organ which occupies so prominent a place in these discussions—the scutellum or malting organ. Under adverse conditions or when vegetative development is unduly accelerated, the scutellum of even the best pedigreed barleys does not retain its excellence. (See Pl. VIII.) The difference between a barley having a good scutellum and one having a poor scutellum is therefore not that the good one is constant, but that under favorable conditions it and it alone will prove to be superior. Normality of development is the means of attaining

the highest success in any form, and any methods that will secure normal development will secure an ideal shape of scutellum, so far as the barley under consideration is capable of such development.

To what extent ideals in barley morphology, and especially in the form of the scutellum, may be affected by breeding, is not as yet fully known. There are many barleys which never produce a desirable malting organ. There are others which, under favorable conditions, invariably do. These facts indicate a usable varietal difference. Whether or not experiments in breeding such hopeful varieties will result in stable forms of scutellum having ideal shape and in epithelial layers having maximum enzymatic power can not at present be stated. But it is safe to assume a priori that these organs are as plastic and capable of improvement as those other parts of the barley plant, such as the shape of the head, the rigidity of the straw, etc., which have been so extensively modified by modern breeding methods. And when these morphological changes are brought about, the writers are certain that the functional qualities which these studies have demonstrated to be correlated with them will show a truly parallel improvement.

In the trials at St. Paul, Minn., in cooperation with the Minnesota Agricultural Experiment Station, a 6-rowed strain with an unusually large scutellum has been isolated from a mixed culture. As it was weak in point of yield and in strength of straw, crosses were made with it upon the Manchuria variety. The large scutellum was transmitted to the F_1 hybrids. In the F_2 generation the large scutellum was retained, but correlated with the weakness of straw and lesser yield of the better malting parent. One or two plants, however, seemed to be more intermediate in character, and if these breed true in the third generation they may form the basis for a superior strain.

FOREIGN BARLEYS.

A word should be said upon the question of the importation of foreign barleys. Barleys of superior quality are readily found abroad, and it would seem a simple matter to select the ones which most nearly satisfy American requirements and to import them for dissemination in this country. The results are, however, uniformly disappointing. The quality of such barleys is in a large part due to their adaptation to their local climatic and soil conditions. Transferred to this country they at once present other characters. In time they become acclimated, but with a few exceptions, such as the Svalof Svanhals, their performance is far from encouraging. The truly successful barleys of the future must be bred in this country. It may be that they will come from foreign stocks; indeed, there are no native sources of seed. New introductions of mixed races are, as a whole, much better material for the selection of breeding strains

than are the imported pedigreed strains. In one case there is a considerable number of subvarieties from which to choose; in the other, there is a single type that has shown superior adaptation to a widely different condition of soil and climate. In any case, whether the means be the acclimatization of established varieties or the production of new ones, the problem is not one of the country at large, but is more or less local. It is also a problem in which only the first steps of progress have been made in this country.

SUMMARY.

The integuments that envelop the ripened seed of barley arise from four sources: The nucellus, the true integuments, the walls of the ovary, and the glumes. Of these, only one has any function other than the protection afforded by dead tissue. The investing membrane of the nucellus develops into the semipermeable membrane, which is found to have remarkable selective powers.

In the development of the barley grain the endosperm develops earlier and more rapidly than the embryo, but it is the last to be completed, inasmuch as starch infiltration continues until the parent plant has ceased to live. The first starch is laid down in the center of the flanks of the grain. Infiltration of starch takes place in centrifugal order. At maturity the starch is less dense about the periphery of the endosperm than in the center. The embryo occupies a lateral position with reference to the endosperm at the proximal end of the grain. The epithelial layer is not functional until near maturity.

Germination is the continuation of the growth of the embryo which was arrested by the maturation of the seed. In its growth the embryo utilizes the food stored in the endosperm.

The conversion of the endosperm is effected by enzymes secreted by the epithelial layer of the scutellum. The cells first affected are those in contact with the epithelial layer. Conversion proceeds from the proximal end slowly toward the distal end, working more rapidly through the layers lying immediately beneath the aleurone layer. Cytase and diastase must both proceed from the scutellum, and the proteolytic ferments most probably owe their origin to the same organ.

The aleurone layer is not a secreting organ. Its function is probably mainly a protective one, although the absorption of its highly nitrogenous contents by the germinating plantlet occurs at a very opportune time in its development.

The greater diastatic power of small-berried barleys is due to the fact that the secreting area is proportionately larger. The area of the epithelial layer as a part of the surface of a spheroid must decrease less rapidly than the volume of the endosperm as the size of the barley grain is lessened.

The efficiency of conversion depends upon the shape and composition of the grain and upon the relative quantity of diastase secreted. The quantity of diastase in turn is dependent upon the size, vigor, and condition of the epithelial layer. The greatest secreting area for a given grain is secured with a scutellum extending well over the edges of the adjacent endosperm, the greatest vigor in an epithelial layer of long, narrow cells, the highest condition of efficiency in a well-matured, well-cured grain.

The ideal grain of barley is one that is broadly oval with a scutellum of the type described. If a large yield of malt extract is desired, the size of the grain should be large; if diastase be the main consideration, the size should be smaller.

Barley grains with pointed ends and a narrow scutellum are to be avoided. Poorly matured grain should also be avoided.

The highest type of the barley grain is secured only when climate, culture, and variety are all favorable.

Pedigreed varieties are essential for securing barleys of superior morphological and physiological quality. Such varieties must for the most part be produced in this country, as imported pedigreed stocks are seldom satisfactory.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE



No. 184

Contribution from the Bureau of Entomology, L. O. Howard, Chief,
April 8, 1915.

(PROFESSIONAL PAPER.)

THE HUISACHE GIRDLER.¹

By M. M. HIGH,

Entomological Assistant, Truck Crop and Stored Product Insect Investigations.

INTRODUCTORY.

The huisache tree is one of a variety of trees and shrubs horticulturally called "wattles" and is probably a native of Texas, although it occurs in Asia, Australia, and to a certain extent in Africa. The flowers furnish the perfume known as frangipanni and the plant is cultivated in southern Europe for the manufacture of perfume. The pods are valuable in tanning and dyeing and the plant is used as an ornamental for the formation of hedges and for shade throughout the Tropics. The bright yellow flowers which are produced in abundance and are large in comparison with those of other acacias render it one of the most beautiful of flowering shrubs of this type. The tree reaches a maximum height of about 35 feet, with a trunk diameter of about 1 foot when properly trained. The trunk is short, the branches somewhat drooping and wide-spreading, forming a beautiful roundheaded tree with light-green feathery foliage.

The huisache tree (*Acacia farnesiana*) of the Southwest has a number of insect enemies, but none is so injurious as a girdler which often damages young trees in such a way as to eradicate them for a time, completely severing them a few inches above ground.

During the summer of 1910, while the writer was engaged, under the direction of Dr. F. H. Chittenden, in the investigation of insects that attack the pecan, this insect, which may be called the huisache girdler, first came under observation. It seemed advisable to keep the species under surveillance in its attacks on the huisache, since it was not known but that pecan trees in the vicinity might become a center of attack at any time, for the reason that two near relatives, *Oncideres cingulata* Say and *Oncideres texana* Horn,

¹ *Oncideres putator* Thom., a beetle of the family Cerambycidae.

NOTE.—This bulletin contains a technical description of an insect infesting the huisache tree of the Southwest. The form of injury is discussed and methods of control are given.

were known to injure the pecan. In any case, the huisache was of sufficient value to warrant a thorough investigation of the girdler, as it holds front rank as a shade tree in the newly developed country in the lower Rio Grande Valley. When the girdlers were first found and observed at work they were exceedingly abundant, and there was no difficulty in collecting a large number in a very short time. A shipment was immediately made to Washington, where Dr. Chittenden identified the insect as *Oncideres putator*, and later Mr. E. A. Schwarz confirmed this determination. Since the girdler was first observed, its work has become more conspicuous each successive season. In 1913, over the infested area as a whole, the beetles appeared in lesser numbers, but in places they were more abundant and the damage was greater than at any time during the four years previous. This would indicate that climatic conditions were not altogether responsible for the decrease, as some of the infested areas were near and in close proximity to one another. It is believed that natural enemies were responsible in part, if not wholly, for the lack of uniformity in distribution in 1913.

The beetles (Pl. I) possess powerful mandibles and saw with ease branches $1\frac{3}{4}$ inches in diameter, completely severing them from the main body of the tree. The eggs, as with other twig girdlers, are deposited in the severed portion of the branch, and never below where it is girdled. The writer has observed as many as 63 girdled branches from one tree, some of which measured 40 millimeters in diameter, the average ranging from 22 to 35 millimeters. (See Pl. II.) No other girdler has been observed to prune branches of this diameter, and all near relatives with which we are acquainted prune or girdle much smaller branches. *Oncideres putator*, unlike some girdlers, does not work so much in pairs, but is often found in colonies as well. The girdling is usually begun a few inches from the base of the branch selected for oviposition or just above where it joins the body of the tree or larger branch, though cases have been observed where the attack was directed to the middle of the branch. At times after the sawing has been begun by one female beetle others will begin depositing eggs before the girdling is very far advanced, apparently with little fear that the branch will not be completely girdled in due time. Young trees are often girdled only a few inches above ground, but where large trees are adjacent the beetles seem to prefer attacking the branches instead. (Pls. III, IV.)

In view of the fact that in the lower Rio Grande Valley and other parts of the Southwest where much development in farm lands is in progress, and where the huisache is oftentimes the only shade tree found upon a farmer's premises, it is thought advisable to present here for publication the life history, food plants, and habits of this girdler, with suggestions for control.

DESCRIPTION.

The beetle belongs to the family Cerambycidae, subfamily Lamiinae, tribe Onciderini. One of the chief characteristics of the tribe is that the front coxal cavities are angulated on the outer side and closed behind; the antennae of the male are much longer than the body, and those of the female are as long as the body.

THE BEETLE.

With this species the antennae of both sexes are longer than the body, and there is little difference in the antennal length in each sex. The beetles (Pl. I) are brownish gray in color, and measure in length from 18 to 24 millimeters, the average length being 22 to 23 millimeters. The mesothorax is wider than in some other species of this genus and measures on an average from 7 to 9 millimeters. In a short time after emerging from the pupal case the beetles lose more or less of their brownish-gray appearance, as the hairs covering their blackish elytra or wing covers are rubbed off, causing them to appear darker in color. This species, like its near relatives, has about one-third of its wing covers more grayish than the remaining two-thirds. The posterior margin of this densely clothed grayish band extends slightly behind the meson. The head and thorax are clothed with brownish hairs a little more densely than the wing-covers when the beetle first emerges, but it gradually loses this brownish tinge for a darker one. Ordinarily there seems to be little difference in size between the males and females. While the writer has found specimens of each sex at times smaller than those of the other, it is evident that the size depends upon the nourishment afforded the larva during its growth, as this in all probability has a bearing on the size of the adult beetle.

After making a large number of measurements it was found that about 60 per cent of the females were from 1 to 1½ millimeters longer than the males, so we may say that the body of the female is slightly larger than that of the male, although this will not be noticed by the collector without the use of a lens. On the other hand, the collector may differentiate the sexes by observing the distal joint or segment of the antennae; in the males this segment is about twice as long as that of the female. The length of this segment in the males runs from 4 to 6½ millimeters, while in the females the average will be from 2 to 3 millimeters. This method of distinguishing the sexes does not require the use of a lens, but one should be careful to see that the distal joint has not been broken off, in the male particularly, for then the specimen will not be very different to the unaided eye from the female. The antennae of both sexes are quite easily broken, and during the latter part of the mating season it is difficult to find a perfect specimen.

THE EGG.

The egg is of a cream-white color when first deposited and from 2.5 to 3 millimeters long, with a diameter about one-third the length. It is elliptical ovate in shape, with one end slightly more pointed than the other. Just before hatching the color changes to yellowish white, when, with the aid of a lens, the embryonic larva is visible.

THE LARVA.

The newly hatched larva, after consuming enough of the eggshell to liberate itself therefrom, measures about 2.8 millimeters in length and is of a pale white color, with the exception of the head, which is light brown, with the mandibles darker.

THE PUPA.

The pupa is white and ranges from 18 to 22 millimeters in length. Later the color changes to light brown, and just before transformation takes place to chocolate brown. When observing the pupa with a lens the dark-colored spines on each segment are very pronounced, particularly on the dorsum.

DISTRIBUTION AND HISTORY.

Oncideres putator has been recorded from the States of Arizona, New Mexico, and Texas, and from Mexico. The species is probably more injurious in Mexico than in this country, as it appears very susceptible to cold, and since breeding takes place during the fall and winter months it apparently could never become a serious pest in localities where the temperature drops much below freezing.

The following note was published in 1912¹ at the meeting of the American Entomological Society, October 24, 1912:

Dr. Skinner exhibited specimens of *Oncideres putator* and said that the species was probably rare in collections. If there is a single brood, this might be accounted for by their late appearance. The specimens were taken by Rehn and Hebard in Sycamore Canyon, Baboquivari Mountains, Pima County, Ariz., October 6, 9, 1910; Palo Alto ranch, Altar Valley, Pima County, Ariz., October 6, 10, 1910; Tucson, Ariz., October 3, 4, 1910; and Snyders Hill, Pima County, Ariz., October 11, 1910.

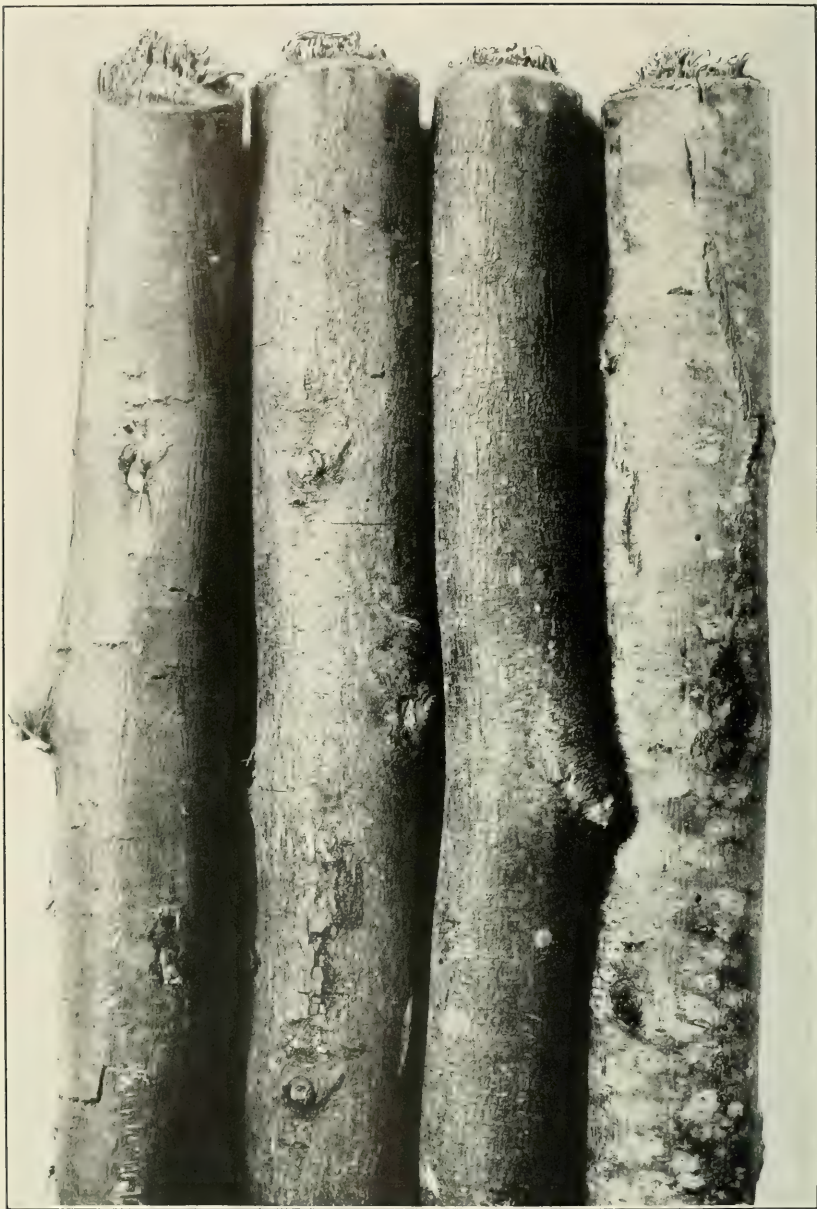
Exact localities have also been recorded by Bates:² Orizaba and Jalapa, Mexico; Belize, Honduras; San Juan, Guatemala; Bugaba, Panama. Mr. Schwarz records the species from Arizona, New Mexico, and western Texas, and the writer has taken it in southern Texas and at Matamoras, Mexico. The species is native to Central America and has come into the United States from Mexico. There are very few data to be found on *Oncideres putator*, while a considerable amount

¹ Ent. News, v. 23, no. 10, p. 484, Dec., 1912.

² Bates, H. W. Longicornia. In Biol. Cent. Amer. Insecta, Coleoptera, v. 5, p. 125, Aug., 1880, and Supplement, p. 367, July, 1885.



THE HUISACHE GIRDLER (*ONCIDERES PUTATOR*). (ORIGINAL.)



WORK OF THE HUISACHE GIRDLER.

Portions of Huisache branches showing method of cutting off by the girdler (*Oncideres putator*) at top; also showing places where skin has been ruptured. Small holes made by secondary borers. Reduced. (Original.)

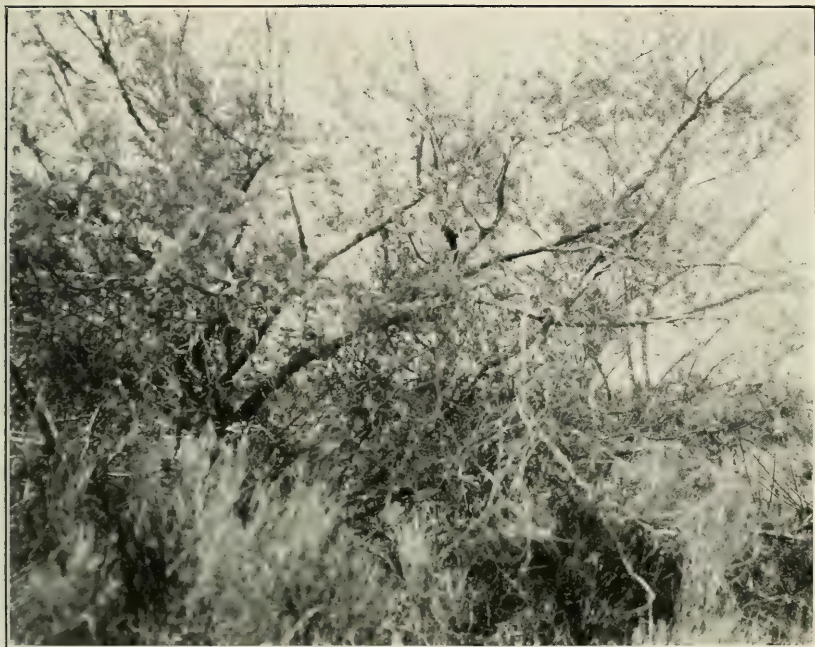


FIG. 1.—WORK OF THE HUISACHE GIRDLER EARLY IN THE SEASON. TWENTY BEETLES COUNTED ON THIS TREE. (ORIGINAL.)



FIG. 2.—TREES WHICH HAVE NOT BEEN SERIOUSLY INJURED BY THE GIRDLER, BUT NO DEAD BRANCHES ALLOWED TO REMAIN ON OR NEAR TREES. (ORIGINAL.)

WORK OF THE HUISACHE GIRDLER.



FIG. 1.—ROW OF HUISACHE TREES ONLY SLIGHTLY DAMAGED BY THE HUISACHE GIRDLER.
(ORIGINAL.)



FIG. 2.—STREET SCENE IN WHICH HUISACHE TREES HAVE BEEN DAMAGED BY THE
HUISACHE GIRDLER. (ORIGINAL.)

WORK OF THE HUISACHE GIRDLER.

of information has been placed on record of *Oncideres cingulata* Say. It appears that some of the early writers on the Onciderini mentioned only the genus *Oncideres* in writing of the depredations of the insects concerned.

The first information received by the Bureau of Entomology in regard to the injurious appearance of *Oncideres putator* in this country was in 1899 at Calabasas, Ariz. The report came from Mr. Morgan R. Wise, who sent specimens of mesquite (*Prosopis juliflora*) which had been girdled by the beetle, together with the statement that this tree was much injured by the girdler. The previous year the beetles had accomplished much damage, so that this year the girdled dead twigs snapped off. It was the opinion of the correspondent that, if this condition was continued, ultimately the mesquite tree would be exterminated by being so badly crippled as to preclude the possibility of its bearing fruit. Mr. Schwarz says that the beetles damage mesquite in western Texas and New Mexico, as well as in Arizona.

The genus *Oncideres* has been discussed by a number of authors, but the writer has been unable to find, in literature on this group, any memoranda on the biology of the species in question. Dr. W. Müller¹ discusses the habits of *Oncideres* in South America, but mentions no specific characteristics, nor does he mention the occurrence of *Oncideres putator*. He states, however, that the species which occur in Brazil frequently sever branches of a diameter of 2 inches or more.

Leng and Hamilton² state that *Oncideres putator* is probably synonymous with *O. cingulata* Say.

The species was originally described by Thomas,³ but no biological notes are included in the description.

FOOD PLANTS.

So far as the writer has been able to observe, the species has in southern Texas five food plants, but the huisache appears to be preferred and the other trees have never been found to be injured in any way comparable with the huisache. The following is a list of the plants or trees on which the species has been found feeding, as well as depositing:

Huisache (*Acacia farnesiana*), mesquite (*Prosopis glandulosa*), huajilla (*Acacia berlandieri*), ratama (*Parkinsonia aculeata*), and *Mimosa lindheimeri*. The host plants are here given in the order of preference by the insect, and no great amount of injury has been

¹ Müller, W. Über die gewohnheiten einiger *Oncideres*-Arten. In Kosmos, Zeitschrift für die gesamte Entwicklungslehre, v. 19, p. 36-38, 1886. Stuttgart.

² Leng, C. W., and Hamilton, John. The Laminae of North America. In Trans. Amer. Ent. Soc., v. 23, p. 101-178, March, 1896. *Oncideres*, p. 140-141.

³ Thomson, James. Phytis, v. 2, no. 5, Paris, Aug., 1868. Revision des groupes des Oncidérites, p. 41-92. *Oncideres putator*, p. 81.

observed to the last three when there was sufficient huisache in close proximity to the emerging beetles. In fact, the greatest amount of damage to "huajilla" and "ratama" was noticed when collections of huisache branches containing larvæ were left near ratama and huajilla trees.

LIFE HISTORY.

The beetles begin to appear early in September and continue to emerge from their pupal cavities until the latter part of November, though most of the brood issues during the month of October. In the laboratory most of the material encaged developed adult beetles by October 12. The adults remain for several days in their pupal cells after they have emerged from the pupal cases before attempting to cut their way out of the pupal cavities through the bark of the branch. Just as soon as they have partaken of a little food, which consists of bark from the branch, and the wing covers are sufficiently hardened, copulation begins. Of specimens observed in the laboratory none began copulating or showed activity before two days after their emergence in the adult stage. This species of *Oncideres*, unlike its near relatives, *Oncideres cingulata* and *O. texana*, does not so frequently work in pairs. The writer has found the beetles working in pairs, but during midseason they occur to a greater or less extent in colonies. The writer has observed as many as 24 on one small tree, and two-thirds of them at times would be females. The males go from one female to another, and do not seem to possess the monogamous instinct.

While making observations on the species during October, 1910, it was decided to see how long a period was required for one unassisted female to prepare the egg cavity and deposit an egg. The first one tried deposited in 1 minute and 35 seconds, another in 4 minutes and 50 seconds, and the next in 4 minutes and 40 seconds. Observations made later show that from 1 to 5 minutes is ordinarily required for the female beetle to deposit. This, however, does not include preparing the cavity to receive the egg, for it generally requires about 10 minutes to prepare the cavity. The beetle begins this cavity by inserting both mandibles as deeply as possible into the bark of the branch that is to be girdled. After forcing the mandibles deep into the bark the beetle draws them together as nearly as she can. Then one is removed and the other worked deeply into the puncture. It is then removed and the other mandible is inserted in the same manner. Later both mandibles are inserted and a tiny chip removed. Then the work begins again with one mandible at a time, until the cavity is prepared to receive the egg. The beetle then reverses its position and forces the ovipositor into the cavity as deeply as possible. Shortly the egg can be seen leaving the body of the beetle. After the egg is inserted the beetle frees herself by withdrawing the

ovipositor, one side at a time, and then she searches for another suitable location. The eggs are ordinarily placed between the layers of bark, and it may here be stated that this species does not deposit particularly about buds or at the base of smaller branches, but may lay her eggs anywhere along the branch girdled. It also might be added that, unlike some, this species of *Oncideres* does not make transverse incisions in the bark, presumably to prevent the growth of the branch from crushing the egg.

There is, in addition, a difference from *Oncideres cingulata* and *O. texana* in the way this species leaves the egg after deposition, in that only a very slight gluey excretion is made in sealing the opening to the egg cavity, and at times there is none at all. This waxy secretion is very conspicuous with the work of the two smaller species.

The larva feeds along gradually, leaving in its burrow behind excrement and castings well packed, which may prevent attack of an enemy from the rear. It has been observed that when a branch not completely severed remained in the top of the tree the young larvæ would often perish, presumably for lack of moisture. On the other hand, the writer has noticed branches that remained several feet above ground all season and which developed beetles during October. It thus appears that it will depend upon the amount of rainfall and climatic conditions generally as to whether the mortality of the larvæ is high in the suspended branches—well up in the tops of the trees. If there should be a moderate rainfall during the winter and spring months, it is thought that the mortality in these suspended branches would be very low, but on the other hand if it should be dry, the mortality would be high. While the larva will stand a very dry atmosphere for several months, its growth will not be as rapid as where there is sufficient moisture to permit constant feeding. Larvæ that have been checked in growth from lack of moisture develop very rapidly when placed in more humid surroundings and appear to obtain their growth just as soon as when left under normal conditions. They could not well do otherwise and thrive in the climate where they have been found most numerous. There is a limit, however, to the amount of moisture the larvæ can stand, for in one instance in the laboratory the mortality was about 70 per cent, and it could be attributed to no other cause than an excess of water. The duration of the larval period is approximately 42 weeks under ordinary conditions, though under the most favorable conditions they may develop in 39 or 40 weeks. Before transforming to pupa the larva prepares a pupal cavity or cell by drawing about it all castings and thus surrounding itself with more or less of a wall that would be difficult for any insect enemy to penetrate. The larva then cuts a hole into the bark and transforms to the pupa. During the growth of the larvæ in the branch

they produce a grinding noise that can be heard several feet away, and when the branch is disturbed this noise is more pronounced. The pupæ in turn make a somewhat similar noise when disturbed, and for this reason one must raise the bark covering in order to know just when transformation takes place.

Before the pupal stage of this species could be had the writer was transferred to Indiana, and the material was taken there in order to obtain the pupæ. The branches were examined frequently during the months of June and July; but no pupæ were observed until August, and the first adult beetle emerged September 15. The duration of the pupal stage is approximately four weeks, with an average mean temperature of 72.5° F.

There is only one generation of this beetle each year, approximately 12 months being required for the life cycle from egg to adult.

LONGEVITY.

The beetles that emerged in the laboratory were kept in confinement without fresh food and lived from 4 to 12 days, while those that were captured, confined in the insectary, and furnished proper food lived from 10 to 21 days, the males dying from 1 to 5 days in advance of the females.

NATURAL ENEMIES.

There are several species of parasites that attack the eggs and larvæ of *Oncideres putator*, one species in particular attacking both egg and larva. The following were reared February 3, 1915, at Brownsville, Tex.: *Chryseida inopinota* Br., *Eurytoma* sp. (Chttn. No. 1921), *Caenophanes* sp. (Chttn. No. 1922), a pteromalid (Chttn. No. 1923), and *Meteorus* sp. (Chttn. No. 1924). It is thought that the larvæ have one or more predaceous enemies, but none has been observed to this writing. It is believed that the southern downy woodpecker (*Dryobates pubescens*) and probably also the Texas woodpecker (*Dryobates scalaris bairdi*) attack the larvæ. While neither of these birds has been found with larvæ, they have been observed at work on branches that contained numerous larvæ of this insect and have left empty chambers behind.

Table I shows something of the mortality early in the season.

TABLE I.—Mortality of the huisache girdler, based on examinations made January 8, 1913.

Number of branch.	Diameter of branch (millimeters).	Number of eggs.	Number of live larvæ.	Number of dead larvæ.
I.....	26	11	0	0
II.....	30	0	58	3
III.....	35	19	153	2
IV.....	28	0	197	14
V.....	32	0	173	17
VI.....	37	7	52	0

On January 13, 1913, four prunings of huisache were stripped of bark, and the following table made:

TABLE II.—*Infestation of the huisache girdler by parasites, based on examinations made January 13, 1913.*

Number of branch.	Diameter of branch (millimeters).	Number of eggs.	Number of living larvæ.	Number of larvæ parasitized.
I.....	36	0	363	11
II.....	30	0	104	5
III.....	25	0	79	6
IV.....	38	59	135	0

These tables give the degree of infestation to a single branch and the mortality of the larvæ at a very early date. The parasites of the larvæ are more numerous a little later in the season, although the egg parasite appears even as early as December 1. This parasite is more effective against the larvæ before they approach a size more than two-fifths of an inch in length; although it attacks the larvæ throughout the season it does not appear in as large number then as it does early in the season.

METHOD OF CONTROL.

Since this insect spends at least 10 months in the severed branch during the egg, larval, and pupal stages, its control is only a matter of collecting the pruned branches and destroying them by burning. This would not be a laborious task, as the girdled branches are so large that it is not difficult to locate them, and as the species does not appear to migrate very rapidly to new territory, this method would nearly eradicate the species in isolated localities, at least, in one or two seasons' time, taking it for granted that a few branches might go unnoticed. (See Pl. III, fig. 2.) The work of burning the branches could best be done from the first week of January to the first of August, as the writer has not observed the laying of any eggs as late as January 1. As the huisache wood burns readily, it should be comparatively easy to collect and destroy pruned branches from a large number of trees in a comparatively short time. In addition to this measure, the beetles might be collected by hand where one has only a small number of trees to guard against this girdler, and in this way the trees could be protected before any damage had been done.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 185

Contribution from the Bureau of Biological Survey
HENRY W. HENSHAW, Chief

Washington, D. C.



April 17, 1915

BIRD MIGRATION

By

WELLS W. COOKE, Assistant Biologist

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INTRODUCTION.

The mystery of bird migration has proved a fascinating subject for speculation and study from earliest times. Long ago it was noticed that birds disappeared in fall and reappeared in spring, but, not knowing where they spent the intervening period, many fanciful theories were advanced to account for their disappearance, as hibernation in hollow trees or in the mud of streams or ponds. Within the century stories were current of whole flocks that were seen to disappear beneath the waves of the Mediterranean to winter in its depths. With later years, however, has come a fuller knowledge of migration, especially of the particular region in which each species passes the cold season, and more definite information in regard to the routes followed in the spring and fall journeys. But fuller knowledge has served to increase rather than to lessen interest in the subject. More persons to-day are watching birds and noting their times of arrival and departure than ever before. Indeed, the Biological Survey has received migration notes from more than 2,000 different observers,

NOTE.—This bulletin discusses the subject of bird migration. Of interest to nature students and to investigators of the economic relation of birds to agriculture.

showing how widespread is the recent development of this important phase of nature study.

The Survey has been collecting data on bird migration for more than 25 years. Investigations by its field naturalists extending over the North American Continent from Panama to the Arctic Circle have resulted in voluminous notes, and in addition assistance of ornithologists throughout the country has been enlisted, so that each year reports are received in spring and fall from hundreds of experienced observers. Lighthouse keepers also have supplied valuable information concerning the destruction of birds at their lights. The facts gathered—over 500,000—from these various sources form the largest amount of data on bird migration ever collected in this country and permit broader and safer generalizations than have hitherto been possible.

A knowledge of the times of migration of birds is essential as a basis for intelligent study of their economic relations and is equally necessary in formulating proper legislation for bird protection—two subjects which form important parts of the work of the Biological Survey.

CAUSES OF MIGRATION.

For more than 2,000 years the phenomena of bird migration have been noted; but while the extent and course of the routes traversed have of late become better known, no conclusive answer has been found to the question, Why do North American birds migrate? Two different and indeed diametrically opposite theories have been advanced to account for the beginnings of these migrations.

According to the more commonly accepted theory, ages ago the United States and Canada swarmed with nonmigratory bird life, long before the Arctic ice fields advancing south during the glacial era rendered uninhabitable the northern half of the continent. The birds' love of home influenced them to remain near the nesting site until the approaching ice began for the first time to produce a winter—that is, a period of inclement weather which so reduced the food supply as to compel the birds to move or starve. As the ice approached very gradually, now and then receding, these enforced retreats and absences—at first only a short distance and for a brief time—increased both in distance and duration until migration became an integral part of the very being of the bird. In other words, the formation of the habit of migration took place at the same time that changing seasons in the year replaced the continuous semitropical conditions of the preglacial eras.

As the ice advanced southward the swing to the north in spring migration was continually shortened and the fall retreat to a suitable winter home correspondingly lengthened, until during the height of the glacial period birds were for the most part confined to Middle and

South America. But the habit of migration had been formed, and when the ice receded toward its present position the birds followed it northward and in time established their present long and diversified migration routes.

Those who thus argue that love of birthplace is the actuating impulse to spring migration call attention to the seeming impatience of the earliest migrants. Ducks and geese push northward with the beginnings of open water so early, so far, and so fast that many are caught by late storms and wander disconsolately over frozen ponds and rivers, preferring to risk starvation rather than to retreat. The purple martins often arrive at their nesting boxes so prematurely that the cozy home becomes a tomb if a sleet storm sweeps their winged food from the air. The bluebird's cheery warble we welcome as a harbinger of spring, often only to find later a lifeless body in some shed or outbuilding where the bird sought shelter rather than return to the sunny land so recently left.

As a matter of fact, however, only a small percentage of birds exhibit these preseasonal migration propensities. The great majority remain in the security of their winter homes until spring is so far advanced that the journey can be made easily and with comparatively slight danger; and they reach the nesting spot when a food supply is assured and all the conditions of weather and vegetation are favorable for beginning immediately the rearing of a family of young.

If, however, a longing for home is considered the main incentive to their northward flight, there arises the question as to why birds desert that home so promptly after the nesting season is over. Data recently collected at the Florida lighthouses by the Biological Survey show that southward migration begins at least by the 10th and probably as early as the 1st of July. Indeed, most birds start south as soon as the fledglings are able to shift for themselves. The orchard oriole, the redstart, and the summer warbler of central United States and the nonpareil of the South all begin their southward journey early in July, long before the fall storms sound a warning of approaching winter and when their insect menu is particularly varied and abundant.

According to the opposite migration theory, the birds' real home is the Southland; all bird life tends by overproduction to overcrowding; and, at the end of the glacial era, the birds, seeking in all directions for suitable breeding grounds with less keen competition than in their tropical winter home, gradually worked northward as the retreat of the ice made habitable vast reaches of virgin country. But the winter abiding place was still the home, and to this they returned as soon as the breeding season was over. Thus, in the case of the orchard oriole mentioned above, many individuals that arrive in southern Pennsylvania the first week in May leave by the middle of July, spending only 2½ months out of the 12 at the nesting site.

Whichever theory is accepted, the beginnings of migration ages ago undoubtedly were intimately connected with periodic changes in the food supply. While North America possesses enormous summer supplies of bird food, the birds must return south for the winter or perish. The overcrowding which would necessarily ensue should they remain in the equatorial regions is prevented by the spring exodus northward. No such movement occurs toward the corresponding southern latitudes. South America has almost no migratory land birds, for bleak Patagonia and Tierra del Fuego offer no inducements to these dwellers of the limitless forests of the Amazon.

The conclusion is inevitable that the advantages of the United States and Canada as a summer home and the superb conditions of climate and food for the successful rearing of a nestful of voracious young far overbalance the hazards and disasters of the journey thither. For these periodical trips did not just happen in their present form; each migration route, however long and complex, is but the present stage in development of a flight that at first was short, easily accomplished, and comparatively free from danger. Each lengthening of the course was adopted permanently only after experience through many generations had proved its advantages.

RELATION OF MIGRATION TO WEATHER.

It may safely be stated that the weather in the winter home has nothing to do with starting birds on the spring migration, except in the case of a few, like some of the ducks and geese, which press northward as fast as open water appears. There is no appreciable change in temperature to warn the hundred or more species of our birds which visit South America in winter that it is time to migrate. It must be a force from within, a physiological change warning them of the approach of the breeding season, that impels them to spread their wings for the long flight.

The habit of migration has been evolved through countless generations, and during this time the physical structure and habits of birds have been undergoing a process of evolution in adaptation to the climate of the summer home. In spring and early summer climatic conditions are decidedly variable, and yet there must be some period that has on the average the best weather for the birds' arrival. In the course of ages there have been developed habits of migration, under the influence of which the bird so performs its migratory movements that on the average it arrives at the nesting site at the proper time.

The word "average" needs to be emphasized. It is the average weather at a given locality that determines the average time of the bird's arrival. In obedience to physiologic promptings the bird migrates at the usual average time and proceeds northward at the

usual average speed unless prevented by adverse weather. Weather conditions are not the cause of the migration of birds; but the weather, by affecting the food supply, is the chief factor which determines the average date of arrival at the breeding grounds. After the bird, in response to physiological changes, has started to migrate, the weather it encounters en route influences that migration in a subordinate way, retarding or accelerating the advance by only a few days, and having usually only slight effect upon the date of arrival at the nesting site.

Local weather conditions on the day of arrival at any stated locality are minor factors in determining the appearance of a given species at that place and time. The major factors in the problem are the weather conditions far to the southward, where the night's flight began, and the relation which that place and time bear to the average position of the bird under normal weather conditions. Many, if not most, instances of arrivals of birds under adverse weather conditions are probably explainable by the supposition that the flight was begun under favorable auspices and that later the weather changed. Migration in spring usually occurs with a rising temperature and in autumn with a falling temperature. In each case the changing temperature seems to be a more potent factor than the absolute degree of cold.

The direction and force of the winds, except as they are occasionally intimately connected with sudden and extreme variations in temperature, seem to have only a slight influence on migration.

DAY AND NIGHT MIGRANTS.

Some birds migrate by day, but most of them seek the cover of darkness. Day migrants include ducks and geese (which also migrate by night), hawks, swallows, the nighthawk, and the chimney swift. The last two, combining business and pleasure, catch their morning or evening meal during a zigzag flight that tends in the desired direction. The daily advance of such migrants covers only a few miles, and when a large body of water is encountered they pass around rather than across it. The night migrants include all the great family of warblers, the thrushes, flycatchers, vireos, orioles, tanagers, shorebirds, and most of the sparrows. They usually begin their flight soon after dark and end it before dawn, and go farther before than after midnight.

Night migration probably results in more casualties from natural causes than would occur if the birds made the same journey by day; but, on the other hand, there is a decided gain in the matter of food supply. For instance, a bird feeds all day on the north shore of the Gulf of Mexico; if, then, it waited until the next morning to make its flight across the Gulf in the daytime it would arrive on the Mexican coast at nightfall and would have to wait until the following

morning to appease its hunger. Thus there would be 36 consecutive hours without food, whereas by night migration the same journey can be performed with only a 12 hours' fast.

Migrating birds do not fly at their fastest. Their migration speed is usually from 30 to 40 miles an hour and rarely exceeds 50. Flights of a few hours a night, alternating with rests of one or more days,



FIG. 1.—Distribution and migration of the bobolink, reedbird, or ricebird (*Dolichonyx oryzivorus*). Of late years the bobolink has been extending its range into newly irrigated districts of western United States (indicated on the map by small encircled areas). Here we can witness the process of a growth in the length of a migration route. So far those individuals, which have added a thousand miles to the route and range into western Nevada, return over the old route and show no tendency to shorten the trip by a direct flight across New Mexico to the Gulf coast of Texas. (See p. 37.)

make the spring advance very slow, averaging for all species not more than 23 miles a day, but with great variations of daily rate among the different species. The exact number of miles which a particular bird makes during one day's journey has not yet been determined, and can not be ascertained until the tagging or banding of birds by means of metal rings is carried out on a far more extensive scale than has yet been possible. If migration were a steady

movement northward with the same individuals always in the van, numerous careful observations might make it possible to approximate the truth; but instead of this, most migrations are performed somewhat after the manner of a game of leapfrog. The van in spring migration is composed chiefly of old birds, and as they reach their nesting places of the previous year they remain to breed. Thus the vanguard is constantly dropping out and the forward movement must depend upon the arrival of the next corps, which may be near at hand or far in the rear. Moreover, in our present state of knowledge we can not say whether a given group of birds after a night's migration keeps in the van on succeeding nights or rests and feeds for several days and allows other groups previously in the rear to assume the lead. It is known that birds do not as a rule move rapidly when migrating in the daytime, but from the meager data available it may be inferred that the speed at night is considerably greater. During day migration the smaller land birds rarely fly faster than 20 miles an hour, though the larger birds, as cranes, geese, and ducks, move somewhat more rapidly. The result of timing nighthawks on several occasions gave a rate of 10 to 14 miles an hour, the former being the more usual speed. This slow rate results from the irregularity of the flight, caused by the birds' capturing their evening and morning meals en route. In the evening the flight lasted about an hour and a half and in the morning about an hour. Thus a distance of approximately 30 miles would be traveled by each individual during the morning and evening flights.

Night migrants probably average longer distances in most of their flights, and this is known to be the case with some species. The purple martin, during the spring of 1884, performed almost its entire migration from New Orleans to Lake Winnipeg during only 12 nights—an average of 120 miles for each night of movement—and some late migrants, like the gray-cheeked thrush, must make still greater distances at a single flight. That most of them can fly several hundred miles without stopping is proved by the fact that they make flights of 500 to 700 miles across the Gulf of Mexico.

DISTANCE OF MIGRATION.

The length of the migration journey varies enormously. A few birds, like the grouse, quail, cardinal, and Carolina wren are nonmigratory. Many a bobwhite rounds out its full period of existence without ever going 10 miles from the nest where it was hatched. Some other species migrate so short a distance that the movement is scarcely noticeable. Thus, meadowlarks are found near New York City all the year, but probably the individuals nesting in that region pass a little farther south for the winter and their places are taken by migrants from farther north. Or part of a species may migrate and

the rest remain stationary, as in the case of the pine warbler and the black-headed grosbeak, which do not venture in winter south of the breeding range. With them fall migration is only a withdrawal from the northern and a concentration in the southern part of the summer home—the warbler in about a fourth and the grosbeak in less than an eighth of the summer area. In the case of the Maryland yellow-throat, the breeding birds of Florida are strictly nonmigratory, while in spring and fall other yellow-throats pass through Florida in their

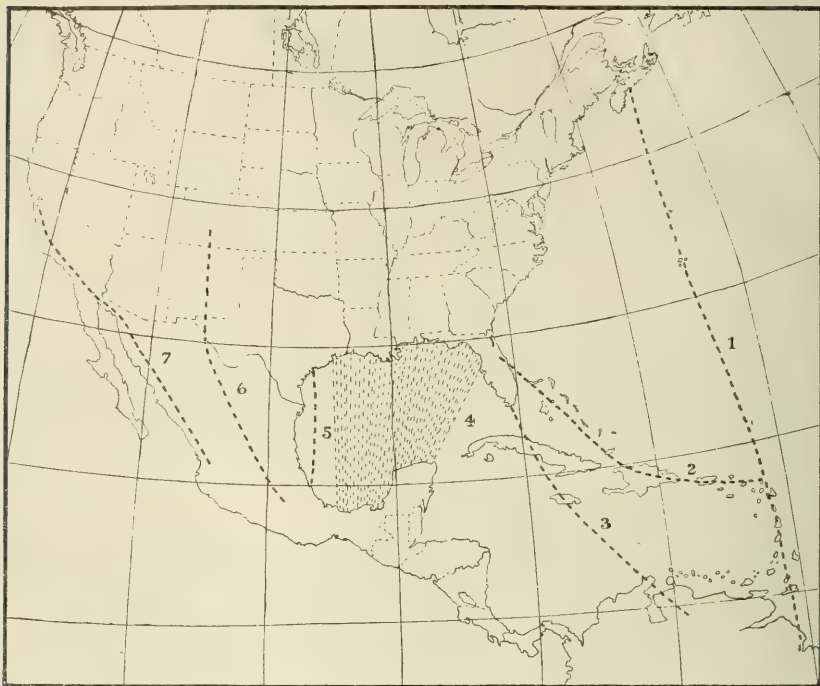


FIG. 2.—Principal migration routes of North America. Most migrants use route No. 4, though this necessitates a flight of 500 to 700 miles across the Gulf of Mexico. A few traverse the more direct route No. 3, and still fewer, route No. 2. Only water birds make the 2,400-mile flight along route No. 1, from Nova Scotia to South America. (See p. 11.)

journeys between their winter home in Cuba and their summer home in New England.

Another variation is illustrated by the robin, which occurs in the middle districts of the United States throughout the year, in Canada only in summer, and along the Gulf of Mexico only in winter. Probably no individual robin is a continuous resident in any section; but the robin that nests, let us say, in southern Missouri, spends the winter near the Gulf, while his hardy Canada-bred cousin is the winter tenant of the abandoned summer home of the southern bird.

Most migratory birds desert the entire region occupied in summer for some other district adopted as a winter home. These two homes



BOBOLINK (*DOLICHONYX ORYZIVORUS*).

[Upper figure, male; lower, female.]



ARCTIC TERN (STERNA PARADISÆA).

are separated by very variable distances. Many species from Canada winter in the United States, as the tree sparrow, junco, and snowflake; others nesting in northern United States winter in the Gulf States, as the chipping, field, Savannah, and vesper sparrows, while more than a hundred species leave the United States for the winter and spend that season in Central or even in South America. Nor are they content with journeying to northern South America, but many cross the Equator and pass on to the pampas of Argentina and a few even to Patagonia. Among these long-distance migrants are some of our commonest birds; the scarlet tanager (Pl. IV) migrates from Canada to Peru; the bobolinks (fig. 1 and Pl. I) that nest in New England probably winter in Brazil, as do purple martins, cliff swallows, barn swallows, nighthawks, and some thrushes, which are their companions both summer and winter. The black-poll warblers that nest in Alaska winter in northern South America, at least 5,000 miles from the summer home. The land bird with the longest migration route is probably the nighthawk, which occurs north to Yukon and south, 7,000 miles away, to Argentina.

But even these distances are surpassed by some of the water birds, and notably by some of the shorebirds, which as a group have the longest migration routes of any birds. Nineteen species of shorebirds breed north of the Arctic Circle, every one of which visits South America in winter, six of them penetrating to Patagonia, a migration route more than 8,000 miles in length.

The world's migration champion, however, is the arctic tern (fig. 3 and Pl. II). It deserves its title of "arctic," for it nests as far north as land has been discovered; that is, as far north as the bird can find anything stable on which to construct its nest. Indeed, so arctic are the conditions under which it breeds that the first nest found by man in this region, only $7\frac{1}{2}^{\circ}$ from the pole, contained a downy chick surrounded by a wall of newly fallen snow that had been scooped out of the nest by the parent. When the young are full grown the entire family leaves the Arctic and several months later they are found skirting the edge of the Antarctic continent.

What their track is over that 11,000 miles of intervening space no one knows. A few scattered individuals have been noted along the United States coast south to Long Island, but the great flocks of thousands and thousands of these terns which range from pole to pole have never been noted by an ornithologist competent to indicate their preferred route and their time schedule. The arctic terns arrive in the far north about June 15 and leave about August 25, thus staying 14 weeks at the nesting site. They probably spend a few weeks longer in the winter than in the summer home, and this would leave them scarcely 20 weeks for the round trip of 22,000 miles. Not less than 150 miles in a straight line must be their daily



FIG. 3.—Distribution of the arctic tern (*Sterna paradisæa*), the champion long-distance migrant of the world. It breeds as far north as it can find land on which to build its nest, and winters as far south as there is open water to furnish it food. The extreme summer and winter homes are 11,000 miles apart, or a yearly round trip of 22,000 miles. (See p. 9.)

task, and this is undoubtedly multiplied several times by their zigzag twistings and turnings in pursuit of food.

The arctic tern has more hours of daylight and sunlight than any other animal on the globe. At the most northern nesting site the midnight sun has already appeared before the birds' arrival, and it never sets during their entire stay at the breeding grounds. During two months of their sojourn in the Antarctic the birds do not see a sunset, and for the rest of the time the sun dips only a little way below the horizon and broad daylight is continuous. The birds therefore have 24 hours of daylight for at least eight months in the year, and during the other four months have considerably more daylight than darkness.

ROUTES OF MIGRATION.

The shape of the land areas in the northern half of the Western Hemisphere and the nature of the surface has tended to great variations in migratory movements. If the whole area from Brazil to Canada were a plain with the general characteristics of the middle section of the Mississippi Valley, the study of bird migration would lose much of its fascination. There would be a simple rhythmical swinging of the migration pendulum back and forth, spring and fall. But much of the earth's surface between Brazil and Canada is occupied by the Gulf of Mexico, the Caribbean Sea, and parts of the Atlantic Ocean, all devoid of sustenance for land birds. The two areas of abundant food supply are North America and northern South America, separated by the comparatively small land areas of Mexico and Central America, the islands of the West Indies, and the great waste stretches of water.

The different courses taken by the birds to get around or over this intervening inhospitable region are almost as numerous as the bird families that traverse them, and only some of the more important routes will be mentioned here. (See fig. 2.)

ISLAND ROUTES.

Birds often seem eccentric in choice of route, and many do not take the shortest line. The 50 species from New England that winter in South America, instead of making the direct trip over the Atlantic involving a flight of 2,000 miles, take a somewhat longer route that follows the coast to Florida and passes thence by island or mainland to South America. What would at first sight seem to be a natural and convenient migratory highway extends from Florida through the Bahamas or Cuba to Haiti, Porto Rico, and the Lesser Antilles and thence to South America (see fig. 2, route 2). Birds that travel by this route need never be out of sight of land; resting places are afforded at convenient intervals and the distance is but little

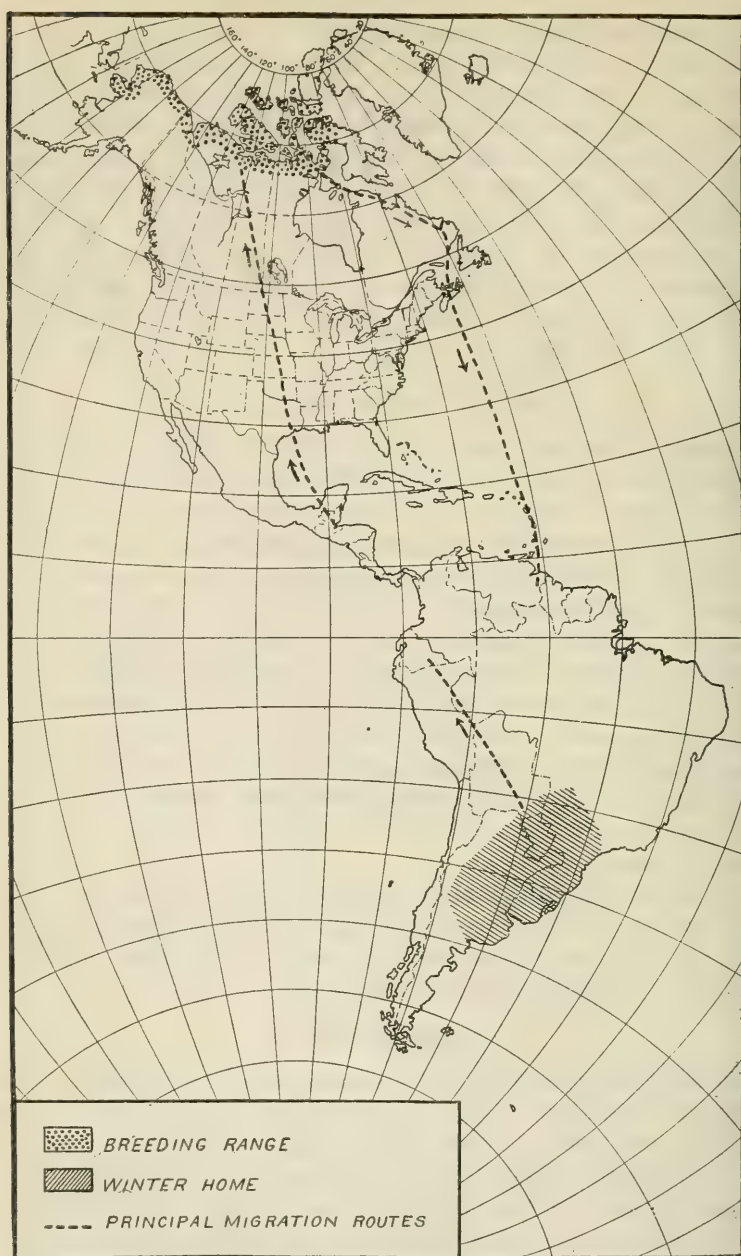


FIG. 4. Distribution and migration of the golden plover (*Charadrius dominicus*). In fall it flies over the ocean from Nova Scotia to South America, 2,400 miles—the longest known flight of any bird. In spring it returns by way of the Mississippi Valley. Thus the migration routes form an enormous ellipse, with a minor axis of 2,000 miles and a major axis stretching 8,000 miles from Arctic America to Argentina. (See p. 17.)

longer than the water route. Yet beyond Cuba this highway is little used. About 25 species continue as far as Porto Rico and remain there through the winter. Only adventurers of some six species gain the South American mainland by completing the island chain. The reason is not far to seek—scarcity of food. The total area of all the West Indies east of Porto Rico is a little less than that of Rhode Island. Should a small proportion only of the feathered inhabitants of the Eastern States select this route, not even the luxuriant fauna and flora of the Tropics could supply their needs.

A still more direct route, but one requiring longer single flights, stretches from Florida to South America via Cuba and Jamaica (see fig. 2, route 3). The 150 miles between Florida and Cuba are crossed by tens of thousands of birds of some 60 different species. About half the species take the next flight of 90 miles to the Jamaican mountains. Here a 500-mile stretch of islandless ocean confronts them, and scarcely a third of their number leave the forest-clad hills for the unseen beyond. Chief among these is the bobolink (Pl. I), which, now well fattened on fall seeds, is so full of strength and energy that the 500-mile flight to South America on the way to the waving pampas of southern Brazil seems a trifle. Indeed, many bobolinks appear to scorn the Jamaican resting point and to compass in a single flight the 700 miles from Cuba to South America. With the bobolink is an incongruous company of traveling companions—a vireo, a kingbird, and a nighthawk that summer in Florida; the chuck-will's-widow of the Gulf States; the two New England cuckoos; the gray-cheeked thrush from Quebec; the bank swallow from Labrador; and the black-poll warbler from far-off Alaska. But the bobolinks so far outnumber all the rest that the passage across the Caribbean from Cuba to South America may with propriety be called the "bobolink route." Occasionally a wood thrush or a tanager joins the assemblage, but the "bobolink route" as a whole is not popular with other birds, and, though many traverse it, they are but a fraction of the multitudes of North American birds that spend the winter in the southern continent.

GULF ROUTES.

The main-traveled highway is that which stretches from north-western Florida across the Gulf, continuing the southwesterly direction which most of the birds of the Atlantic coast follow in journeying to Florida (see fig. 2, route 4). A larger or smaller percentage of nearly all the species bound for South America take this roundabout course, quite regardless of the several-hundred-mile flight over the Gulf of Mexico.

The birds east of the Allegheny Mountains move southwest in the fall, approximately parallel with the seacoast, and apparently keep

this same direction across the Gulf to eastern Mexico. The birds of the central Mississippi Valley go southward to and over the Gulf. The birds between the Missouri and the edge of the plains and those

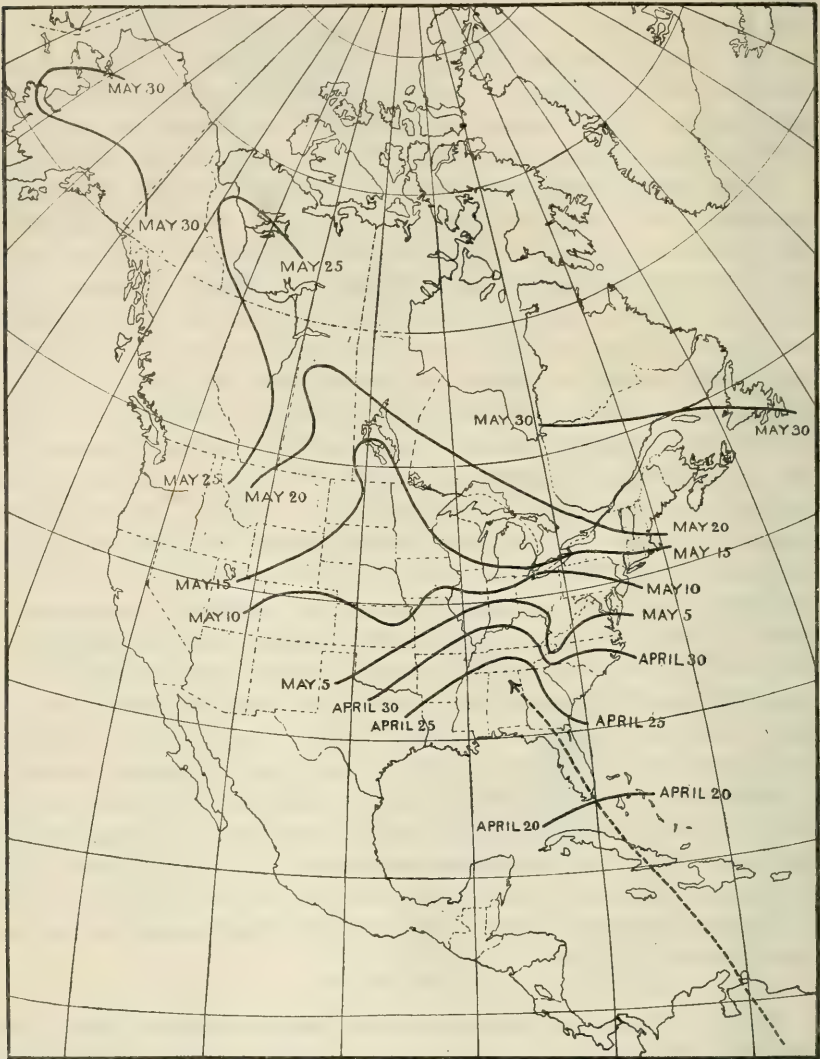


FIG. 5.—Migration of the black-poll warbler (*Dendroica striata*). This is a night migrant and flies directly across the West Indies in contradistinction to the cliff swallow (fig. 6), which is a day migrant and flies around the Gulf of Mexico (see p. 19). The heavy solid isochronal lines show the places at which birds arrive at the same time. As birds move northward, these lines are farther apart, showing that the birds are moving faster; from April 30 to May 10, the average speed is about 30 miles a day, while from May 25 to May 30 it is more than 200 miles a day. (See p. 43.)

of Canada east of the Rocky Mountains move southeastward and south until they join the others in their passage of the Gulf. In other words, the great majority of North American birds bound for a

winter's sojourn in Central or South America elect a short cut across the Gulf of Mexico in preference to a longer land journey by way of Florida or Texas. In fact, millions of birds cross the Gulf at its widest part, which necessitates a single flight of 500 to 700 miles. It might seem more natural for the birds to make a leisurely trip along the Florida coast, take a short flight to Cuba, and thence a still shorter one of less than 100 miles to Yucatan—a route only a little longer and involving much less exposure. Indeed, the earlier naturalists, finding the same species both in Florida and in Yucatan, took this probable route for granted, and for years it has been noted in ornithological literature as one of the principal migration highways of North American birds. As a fact, it is almost deserted except for a few swallows, some shorebirds, and an occasional land bird storm driven from its accustomed course, while over the Gulf route night after night for nearly eight months in the year myriads of hardy migrants wing their way through the darkness toward an unseen destination.

To the westward a short route (see fig. 2, route 4) stretches a few hundred miles from the coast of Texas to northern Vera Cruz. It is adopted by some warblers, as the Kentucky, the worm-eating, and the golden-winged, and a few other species, which seek in this way to avoid a region scantily supplied with moist woodlands.

OTHER ROUTES.

Still farther west are two routes (see fig. 2, routes 6 and 7) which represent the land journeys of those birds from western United States that winter in Mexico and Central America. Their trips are comparatively short; most of the birds are content to stop when they reach the middle districts of Mexico and only a few pass east of the southern part of that country.

The routes as outlined on the map must not be considered as representing distinctly segregated pathways with clearly defined borders. On the contrary, they are merely convenient subdivisions of the one great flightway which extends from North to South America. There is probably no single mile in the whole east and west line from northern Mexico to the Lesser Antilles which is not crossed each fall by migrating birds. What is meant is that the great bulk of both species and individuals cross the Gulf to eastern Mexico, while to the eastward their numbers steadily diminish.

The map of the migration routes (fig. 2) shows route No. 1 that has not yet been described. It extends in an approximately north and south line from Nova Scotia to the Lesser Antilles and the northern coast of South America. Though more than a thousand miles shorter than the main migration route, it is not employed by any

land bird. But it is a favorite fall route for thousands of water birds, notable among which is the golden plover.

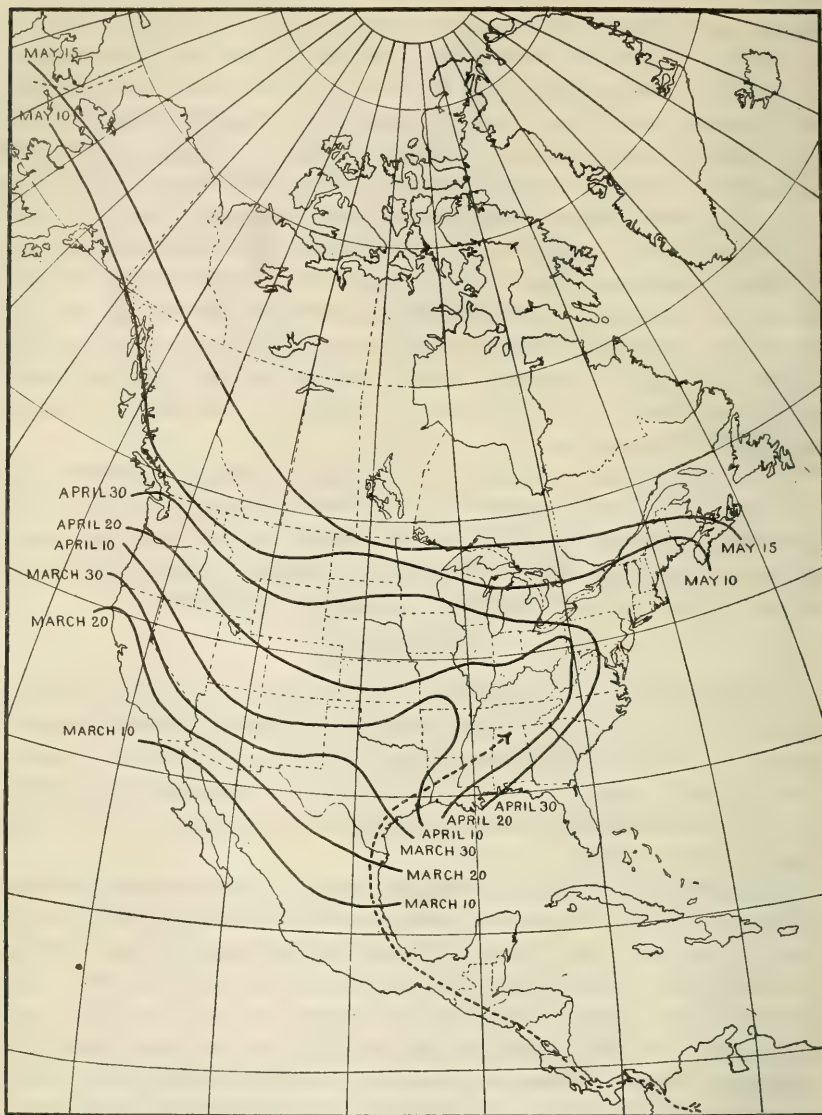


FIG. 6.—Migration of the cliff swallow (*Petrochelidon lunifrons*). This is a day migrant, feeding on the wing; hence it keeps near land and journeys around the Gulf of Mexico, instead of flying across it as is done by the black-poll warbler (fig. 5) which migrates at night. (See pp. 19 and 26.)

The journey of this plover is wonderful enough to be given in detail. Its most striking characteristics are a single flight of 2,400 miles—the longest known flight of any bird—and an elliptical migration route following different paths for the spring and the fall

migration (see fig. 4). In the first week of June the golden plover arrive at their breeding grounds on the "barren grounds" above the Arctic Circle far beyond the tree line. While the lakes are still ice-bound they build their shallow nests in the moss only a few inches above the frozen ground. As soon as the young are old enough to care for themselves fall migration is begun by a trip to the Labrador coast, where the plover fatten for several weeks on the abundant native fruits. Thence a short trip across the Gulf of St. Lawrence brings them to Nova Scotia, the starting point for their extraordinary ocean flight due south to the coast of South America, their objective point. In fair weather the birds fly past Bermuda without stopping, and many flocks do not pause at the first of the Antilles but keep on to the larger islands and sometimes even to the mainland of South America, accomplishing the whole 2,400 miles without pause or rest. How many days are occupied in the trip may never be known. Most migrants fly at night and rest in the day or vice versa, but the plover fly both night and day. After a short stop on the northern coast of South America they resume their journey and travel overland to the pampas of Argentina. Here they remain from September to March (the summer of the Southern Hemisphere) free from the domestic responsibilities of their northern summer home. The native birds of Argentina are at the time engrossed in family cares, but no wayfarer from the north ever nests in the south.

After a six months' vacation here the plover start back to the Arctic, but by an entirely different route. They cross northwestern South America and the Gulf of Mexico, reaching the United States along the coasts of Louisiana and Texas. Thence they move slowly up the Mississippi Valley and by early June are again at the nesting site on the Arctic coast. The round trip has taken the form of an enormous ellipse, with a minor axis of 2,000 miles and a major axis stretching 8,000 miles from Arctic America to Argentina.

The golden plover of the Atlantic Ocean, though often flying 2,400 miles continuously, could make intermediate stops if they so desired. Sometimes, when storm driven, they seek the nearest land and not infrequently appear at Cape Cod and Long Island. Some flocks stop for longer or shorter periods at Bermuda and on the islands of the Lesser Antilles. To the golden plover of the Pacific, however, no such convenient harbors of safety are available. Their flight of approximately equal length (2,000 miles) takes them across an islandless sea from Alaska to Hawaii. No matter what storms are encountered, when once they are started over the ocean they must continue to the end or perish. It seems incredible that any birds can lay a course so straight as to attain these small islands in midocean, 2,000 miles from the Aleutian Islands on the north, 2,000 miles from

California on the east, and 3,700 miles from Japan on the west. And yet year after year golden plover in considerable numbers fly in fall

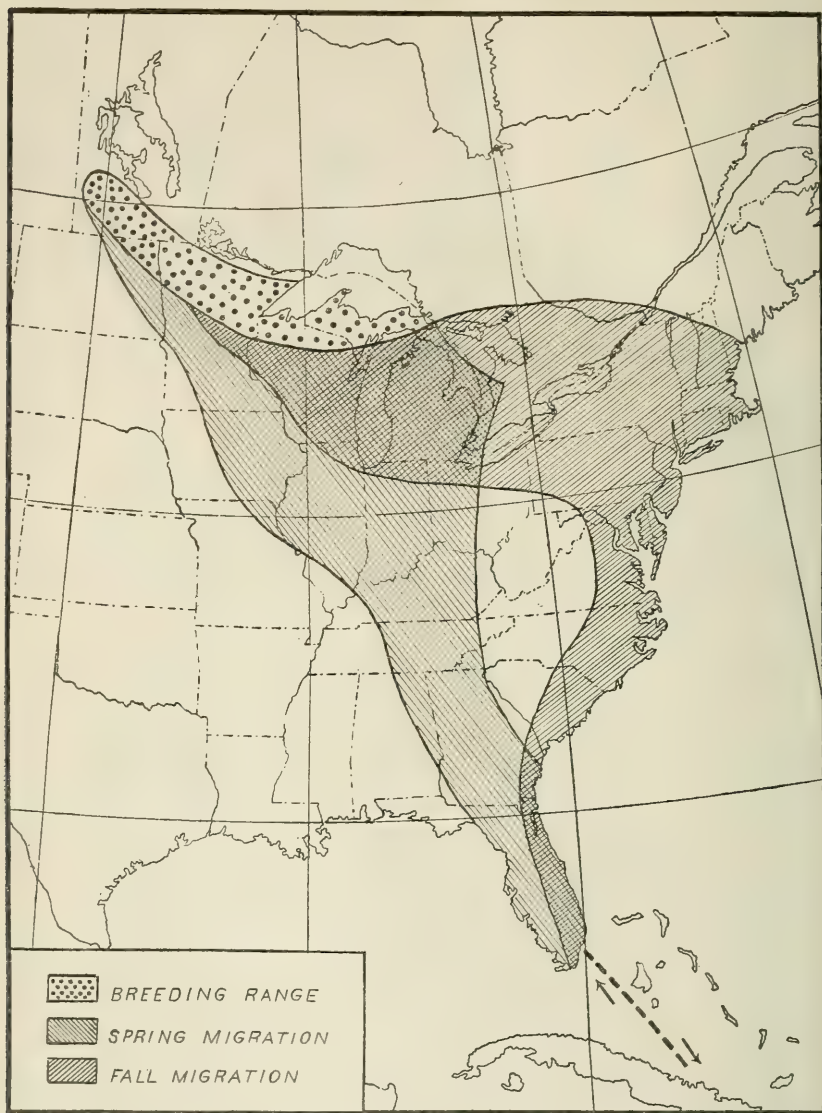


FIG. 7.—Breeding range and migration routes of the Connecticut warbler (*Oporornis agilis*). Breeding in northern United States and southern Canada, it migrates east in fall to New England, then follows the Atlantic coast to Florida and across the West Indies to the winter home in South America. In spring after its return to Florida it crosses the Allegheny Mountains and passes up the Mississippi Valley to its summer home. (See p. 21.)

from Alaska to Hawaii, spend the winter there, and the next spring wing their way back again to nest in Alaska.

DIRECT AND CIRCUITOUS MIGRATION ROUTES.

All black-poll warblers winter in South America. Those that are to nest in Alaska strike straight across the Carribbean Sea to Florida and northwestward to the Mississippi River (see fig. 5). Then the direction changes and a course is laid almost due north to northern Minnesota in order to avoid the treeless plains of North Dakota. But when the forests of the Saskatchewan are reached the northwestward course is resumed and, with a slight verging toward the west, is held until the nesting region in the Alaska spruces is attained.

Cliff swallows in South America are winter neighbors of the black-poll warblers. But when in early spring nature prompts the swallows which are to nest in Nova Scotia to seek that far-off land, situated exactly north of their winter abode, they begin their journey by a westward flight of several hundred miles to Panama. Thence they move leisurely along the western shore of the Caribbean Sea to Mexico (see fig. 6), and, still avoiding any long trip over water, go completely around the western end of the Gulf. Hence as they cross Louisiana their course is directly opposite to that in which they started. A northeasterly flight from Louisiana to Maine and an easterly one to Nova Scotia completes their spring migration. This circuitous route has increased their flight more than 2,000 miles.

Why should the swallow select a route so much more roundabout than that taken by the warbler? The explanation is simple. The warbler is a night migrant. Launching into the air soon after night-fall, it wings its way through the darkness toward some favorite lunch station, usually one to several hundred miles distant, and here it rests and feeds for several days before undertaking the next stage of its journey. Its migration consists of a series of long flights from one feeding place to the next, and naturally it takes the most direct course between stations, not avoiding any body of water that can be compassed in a single flight.

The swallow, on the other hand, is a day migrant. It begins its spring migration several weeks earlier than the warbler and catches each day's rations of flying insects during a few hours of slow evolutions, which at the same time accomplish the work of migration. Keeping along the insect-teeming shores, the 2,000 extra miles thereby added to the migration route are but a tithe of the distance the bird covers in pursuit of its daily food.

The cliff swallow spends the winter in Brazil and Argentina and breeds from Mexico to Alaska. Writing 10 years ago concerning it, the author made the following statement:

It would be expected to reach the United States in spring first in southern Florida and Texas, later in the Rocky Mountains, and finally on the Pacific coast. As a matter of fact, the earliest records of the bird's appearance in spring come from northern

central California, where it becomes common before the first arrivals are usually noted in Texas or Florida. The route the species takes from Brazil to California is one of the yet unsolved migration puzzles.

Since the above was written much additional information has been obtained on the movements of this species, and now it is possible to

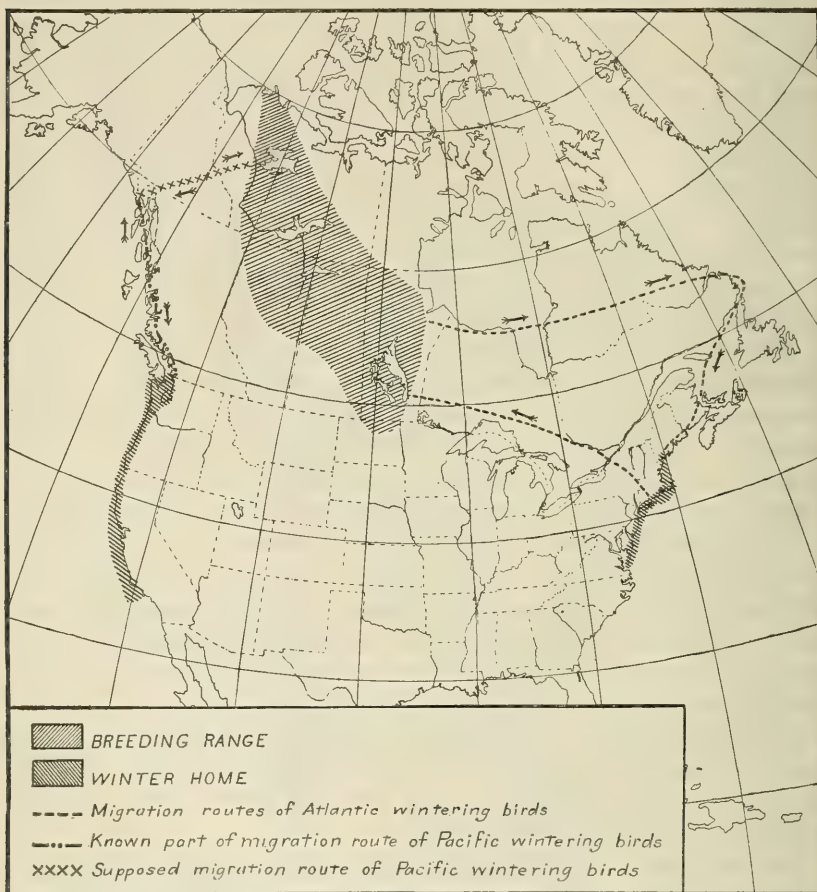


FIG. 8.—Distribution of the white-winged scoter (*Oidemia deglandi*). Birds wintering on the Atlantic coast follow an elliptical migration route, passing eastward in fall to the Labrador coast and returning the following spring by a route from Long Island Sound northwestward directly to the breeding grounds. Birds wintering on the Pacific coast are known to migrate spring and fall along the coast between Washington and southern Alaska, but where they cross the mountains can only be surmised, for they have never been noted anywhere on the 500-mile strip between the Pacific Ocean and the Mackenzie River, and apparently this part of the migration route is accomplished at a single flight. (See p. 21).

solve this migration puzzle. It is now known that the cliff swallows go around the Gulf of Mexico instead of across it. The isochronal lines on the migration map show that the birds advance along the Pacific coast of Mexico faster than along the Gulf side, so that on March 20, when the van has not quite reached the lower Rio Grande of Texas, it is already far north in California.



WHITE-WINGED SCOTER (*OIDEMIA DEGLANDI*).

[Lower, figure, male; upper female.]



SCARLET TANAGER (*PIRANGA ERYTHROMELAS*).

[Upper figure, male; lower, female.]

ECCENTRIC MIGRATION ROUTES.

The normal migration route for the birds of eastern North America is a northeast and southwest course approximately parallel with the trend of the Atlantic coast; the birds breeding in the interior take a line of flight parallel in general with the course of the three great river valleys—those of the Mississippi, the Red, and the Mackenzie—that form a highway rich in food supplies between their winter and summer homes. Many birds, however, follow migration routes widely differing from the normal. One of the most extreme exceptions is that of the marbled godwit. Formerly a common breeder in North Dakota and Saskatchewan, some individuals on starting for their winter home in Central America took a course almost due east to the Maritime Provinces of Canada and thence followed the Atlantic coast to Florida and continued southward; others went in the opposite direction, traveling westward to southern Alaska and southward along the Pacific coast to Guatemala. Thus birds which were near neighbors in summer became separated nearly 3,000 miles during migration, to settle finally in close proximity for the winter.

The Connecticut warbler, choosing another eccentric course, adopts different routes for its southward and northward journeys (see fig. 7). All the individuals of this species winter in South America, and so far as known all go and come by the same direct route between Florida and South America across the West Indies; but north of Florida the spring and fall routes diverge. The spring route leads the birds up the Mississippi Valley to their summer home in southern Canada; but fall migration begins with a 1,000-mile trip almost due east to New England, whence the coast is followed southwest to Florida. The Connecticut warbler is considered rare, but the multitudes that have struck Long Island lighthouses during October storms show that the species is at least more common than would be judged from spring observations, and also how closely it follows the coast line during fall migration. The breeding of the Connecticut warbler offers a fruitful field of investigation for some bird lover during a summer vacation, for there undoubtedly is a large and as yet undiscovered breeding area in Ontario north of Lakes Huron and Superior. Incidentally this route of the Connecticut warbler is a conclusive argument against the theory that migration routes always indicate the original pioneer path by which the birds invaded the region of their present summer homes.

Another species having an elliptical migration route is the white-winged scoter (fig. 8 and Pl. III). This duck breeds near fresh water in the interior of Canada and winters entirely on the ocean along the Atlantic and Pacific coasts of the United States. From its summer home west of Hudson Bay individuals that are to winter on the Atlantic travel 1,500 miles almost due east to the coast of the most

eastern part of Labrador; thence they cross the Gulf of St. Lawrence and follow the New England coast to their winter home, which extends from southwestern Maine to Chesapeake Bay, with the center of abundance off Long Island and Massachusetts. In spring



FIG. 9.—Breeding and wintering ranges of the western tanager (*Piranga ludoviciana*). It would be supposed that the birds nesting in the northeastern part of the breeding range would reach their summer home by the most direct route, through western Texas and along the eastern foothills of the Rocky Mountains. The next map (fig. 10) shows that they take a peculiarly circuitous route. (See p. 23.)

the birds return to their breeding grounds by an inland route traversing the valleys of the Connecticut, Hudson, and Ottawa Rivers. Individuals that winter along the Pacific coast from Washington to southern California are known to pass by thousands up and down the coast as far north as that coast has a generally north and south

trend; but as soon as the coast line turns westward near the north-western point of British Columbia the birds disappear and are not known anywhere in the 500-mile strip between the Pacific coast and the Mackenzie Valley. Apparently this region is crossed at a single flight from the salt water of the coast to the fresh-water summer home on the great lakes of the Mackenzie Valley.

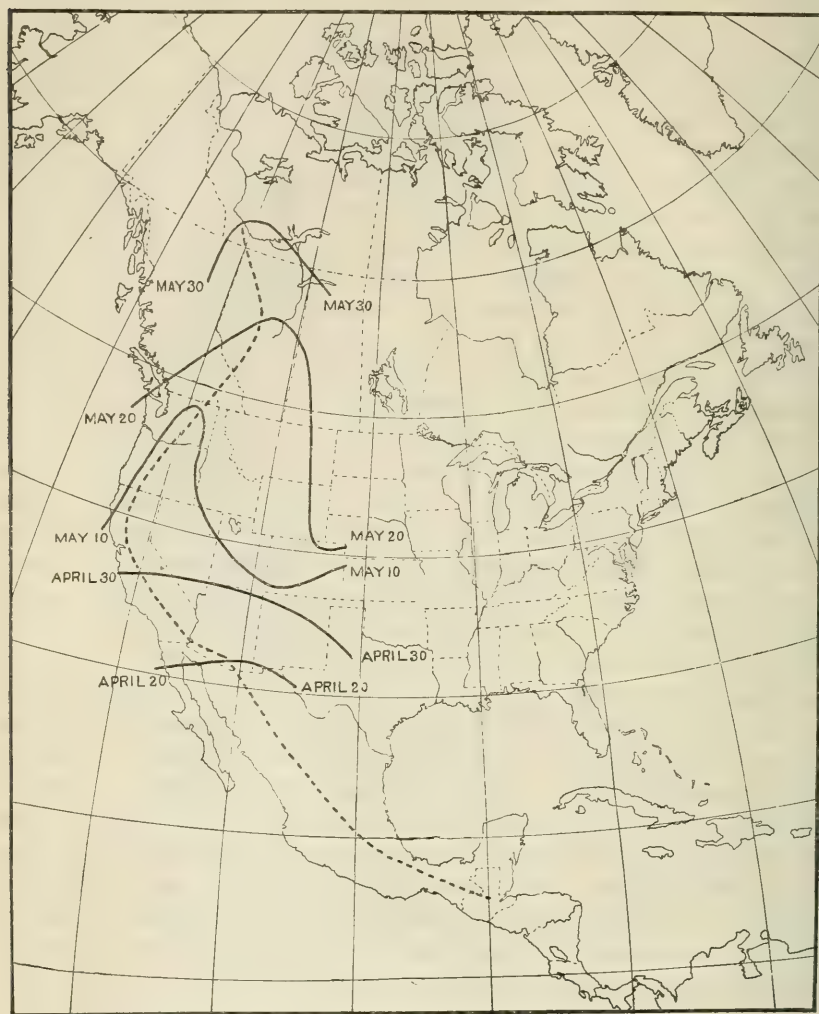
A migration route entirely different from any thus far mentioned is that of the western tanager, or Louisiana tanager, as it was formerly called. From its winter home in Guatemala (see fig. 9) it enters the United States about April 20; another 10 days and the van is in central New Mexico, Arizona, and southern California, marking an approximately east and west line (see fig. 10). The next 10 days the easternmost birds advance only to southern Colorado, while the western have reached northern Washington. May 10 finds the line of the van extending in a great curve from Vancouver Island northeast to central Alberta and thence southeast to northern Colorado. It is evident that the Alberta birds have not reached their breeding grounds by way of the eastern slope of the Rocky Mountains, a route which would naturally be taken for granted by anyone examining a map of the winter and summer homes. On the contrary, these Alberta breeders must have come by way of the Pacific coast to southern British Columbia and then crossed over the main range of the Rocky Mountains, which at this season (May 20) are still cold and partly covered with snow.

Still another strange migration route, probably unique, is that of the Ross snow goose (see fig. 11). This species breeds on the Arctic islands north of Mackenzie and in fall migration it travels up the valleys of the Mackenzie and Athabaska Rivers in company with thousands of other waterfowl bound for their winter homes on the coasts of eastern United States and the Gulf of Mexico. But on reaching the northern boundary of the United States the Ross goose parts company with its traveling companions, and while they continue south and southeast along the usual migration route it turns to the southwest, crosses the main range of the Rocky Mountains, and settles for the winter in California.

WIDE AND NARROW MIGRATION ROUTES.

The shape of North America tends to a converging of the lines of migration toward the Gulf of Mexico, and consequently the east and west breadth of the migration route just south of the United States is usually less than the corresponding breadth of the breeding territory. The extent to which migration routes contract varies greatly with different species. The redstart represents one extreme (see fig. 12), where the lines of migration are carried far eastward to include the Bahamas and the Antilles, while they also extend southwestward

into Mexico. Thus the migrating hosts present a broad front with an east and west extension of 2,500 miles from Mexico to the Lesser Antilles.



† FIG. 10.—Migration of the western tanager (*Piranga ludoviciana*). The birds that arrive in eastern Alberta May 20 can not have come by way of Colorado and Wyoming, as would be expected (see fig. 9), for on this date the van of migration along the eastern foothills of the Rocky Mountains has only just reached northern Colorado. The isochronal lines of migration point to the conclusion that these birds migrate north through California and then cross the Rocky Mountains of British Columbia to Alberta, though at this season (May 20) these mountains are largely covered with snow. (See p. 23.)

The opposite extreme, a narrow migration route, appears in the case of the rose-breasted grosbeak (see fig. 13). The breeding range extends from Nova Scotia to central Alberta, 2,500 miles, and the migration lines converge until the grosbeaks leave the United

States along 800 miles of the Gulf coast from western Florida to central Texas.

The case of the bobolink is typical of many species nesting in North America and wintering entirely in South America (see fig. 1). The summer home extends from Cape Breton Island to Saskatchewan, 2,300 miles, and the migration lines converge toward southeastern United States and then strike directly across the West Indies for South America. In this part of their journey the migration path contracts to an east and west breadth of about 800 miles, and a very large percentage of the birds restrict themselves to the eastern half of it. In South America the region occupied during the winter has about one-fifth the breadth and one-third the area of the breeding range.

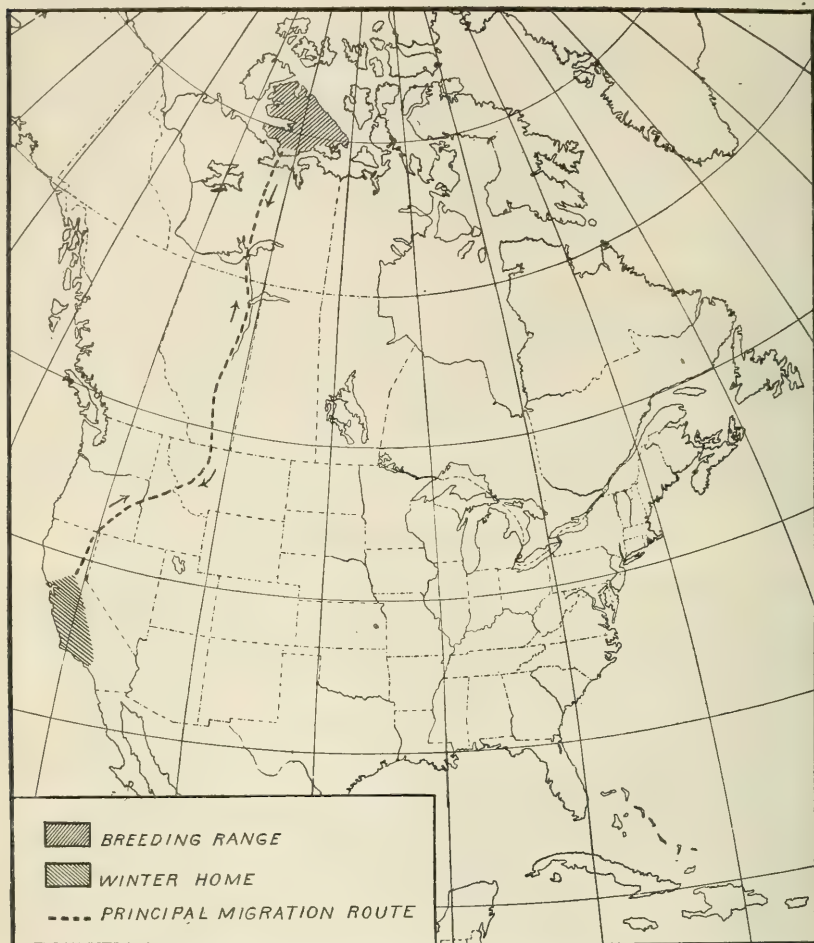
The route of the scarlet tanager is an extreme example of narrowness of the path traveled twice a year between winter and summer homes (see fig. 14). The breeding range extends 1,900 miles from New Brunswick to Saskatchewan. The migration range is contracted to 800 miles from Florida to Texas as the birds leave the United States. The migration lines continue to converge until in southern Central America the limits are not more than 100 miles apart.

SLOW AND RAPID MIGRATION.

The black-and-white warbler presents some interesting phases of migration. It winters in Central America, Mexico, the West Indies, and the peninsula of Florida (see fig. 15). Ordinarily it would not be possible to distinguish the spring migrants in Florida from the wintering birds, and the advance of migration could not be noted until the migrants had passed north of the winter range, but records of black-and-white warblers striking lighthouses of southern Florida indicate the beginning of the birds' northward migration flight from Cuba. This occurs on the average on March 4, and the birds do not appear in southern Georgia beyond their winter range on the average until March 24. Thus a period of 20 days is taken for the van of migration to move 400 miles across Florida, an average rate of 20 miles per day. This rate is about the slowest of all North American birds and is only slightly increased throughout the whole spring migration up the Atlantic coast to Nova Scotia (see fig. 16), where the birds arrive about May 20, having averaged less than 25 miles a day for the whole 77 days after leaving Cuba.

Migration along the western border of the range is fully as slow as along the Atlantic coast; on the average, the first arrive at Kerrville, Tex., March 9 and in northern North Dakota May 10, having traveled 1,300 miles in 60 days, or 22 miles a day. Thence the speed is more than doubled to the northwestern limit of the range in the Mackenzie Valley. (See fig. 16.)

Incidentally it may be remarked that the black-and-white warbler is one of the very few migrants which arrive in Texas and Florida before they appear at the mouth of the Mississippi. The van of most species reaches southern Louisiana earlier than southern Texas.



† FIG. 11.—Distribution and migration of the Ross snow goose (*Chen rossii*). This is apparently the only species that breeds on the Arctic islands, migrates south in fall through the Mackenzie Valley, and when it reaches the United States, instead of passing south and east to the Mississippi Valley, turns westward, crosses the Rocky Mountains, and winters in California. (See p. 23.)

The cliff swallow is another species with a slow migration schedule (see fig. 6). It must start northward very early, since by March 10 it is already 2,500 miles from the winter home and yet averages only 25 miles a day for the next 20 days while rounding the western end of the Gulf of Mexico. It more than doubles this rate while passing up the Mississippi and Ohio River valleys. The crossing of the Allegheny Mountains comes next, and there are only 200 miles of progress

to show for the 10 days' flight. By this time spring has really come east of the Alleghenies, and the swallow travels 60 miles a day to its summer home in Nova Scotia. It is to be noted that the swallow works up to high rates of speed only when it is traveling on the diagonal, and that except during the 10 days spent in crossing the mountains each 10 days' travel covers approximately 5 degrees of latitude.

One of the best examples of rapid migration is that of the gray-cheeked thrush. This bird remains in its South American winter home so long that it does not appear in southern United States until late April—April 25 near the mouth of the Mississippi and April 30 in northern Florida (see fig. 17). The last week in May finds the bird in extreme northwestern Alaska, the 4,000-mile trip from Louisiana to Alaska having been performed in about 30 days, or about 130 miles a day.

Generally the later in the season a bird migrates the greater is its average speed, but not necessarily the distance covered in a single night. The early migrants encounter much bad weather and after one night's migration usually delay several days before making the next flight. The later migrant finds few nights too unfavorable for advancing, so that short flights taken on successive nights greatly raise the average migration speed.

HOW BIRDS FIND THEIR WAY.

How do migrating birds find their way? They do not journey haphazard, for the familiar inhabitants of our dooryard martin boxes will return next year to these same boxes, though meanwhile they have visited Brazil. If the entire distance were made overland, it might be supposed that sight and memory were the only faculties exercised. But for those birds that cross the Gulf of Mexico, and more especially for the golden plover and its ocean-crossing kindred, something more than sight is necessary. Among day migrants sight probably is the principal guide, but it is noticeable that these seldom make the long single flights so common with night migrants.

Sight undoubtedly does play a part in guiding the night journeys also. On clear nights, especially when the moon shines brightly, migrating birds fly high and the ear can scarcely distinguish their faint twitterings; if clouds overspread the heavens, the flocks pass nearer the earth and their notes are much more audible; and on very dark nights the flutter of vibrant wings may be heard but a few feet overhead. Nevertheless, something besides sight guides these travelers in the upper air. In Alaska a few years ago members of the Biological Survey on the Harriman expedition went by steamer from the island of Unalaska to Bogoslof Island, a distance of about 60 miles. A dense fog shut out every object beyond a hundred yards. When the steamer was halfway across, flocks of murre, returning to

Bogoslof after long quests for food, began to break through the fog-wall astern, fly parallel with the vessel, and disappear in the mists ahead. By chart and compass the ship was heading straight for the

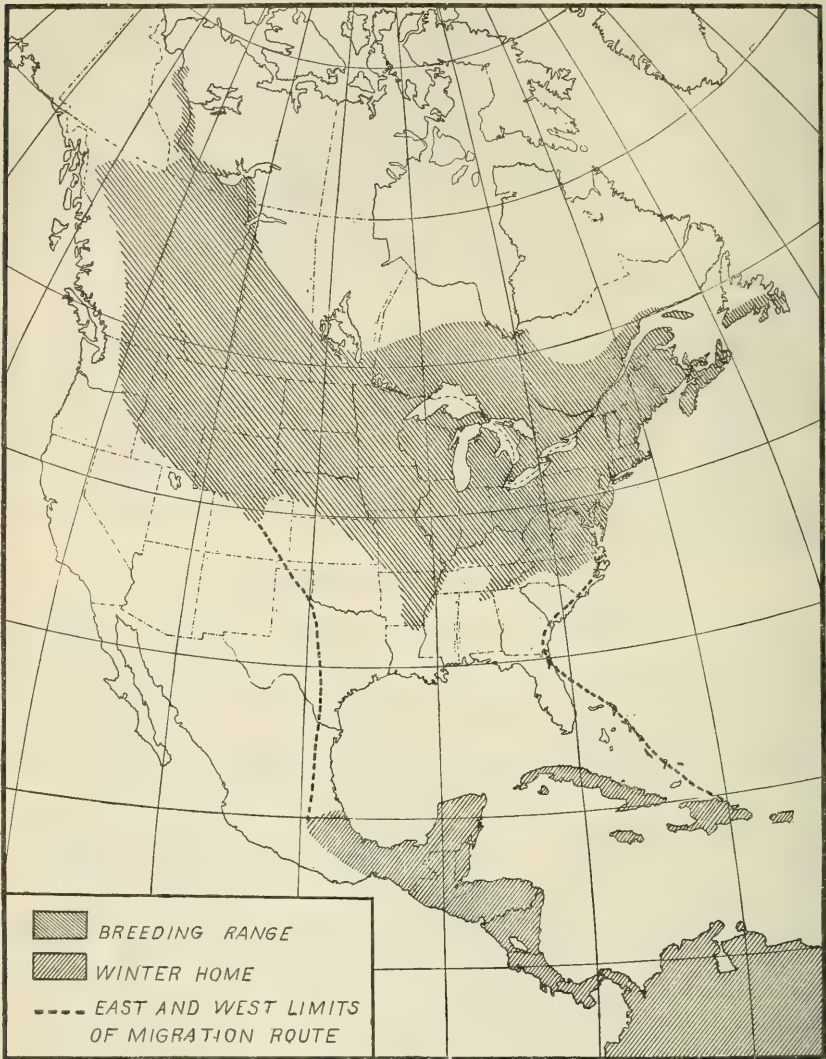


FIG. 12.—Distribution and migration of the redstart (*Setophaga ruticilla*). An example of a wide migration route. Redstarts cross all parts of the Gulf of Mexico and pass from Florida to Cuba and through the Bahamas, so that their migration route has an east and west width of more than 2,000 miles. (See p. 23.) The opposite of this (a narrow migration route) is shown by the distribution map of the rose-breasted grosbeak, fig. 13.

island, but its course was no more exact than that taken by the birds. The power which carried them unerringly home over the ocean wastes, whatever its nature, may be called a sense of direction. We recognize in ourselves the possession of some such sense, though

imperfect and frequently at fault. Doubtless a similar but vastly more acute sense enables the murre, flying from home and circling wide over the water, to keep in mind the direction of their nests and return to them without the aid of sight.

But even the birds' sense of direction is not infallible. Reports from lighthouses in southern Florida show that birds leave Cuba on cloudy nights, when they can not possibly see the Florida shores, and safely reach their destination, provided no change occurs in the weather. But at fickle equinoctial time many flocks starting out under auspicious skies find themselves suddenly caught by a tempest. Buffeted by the wind and their sense of direction lost, these birds fall easy victims to the lure of the lighthouse. Many are killed by the impact, but many more settle on the framework or foundation until the storm ceases or the coming of daylight allows them to recover their bearings.

A favorite theory of many American ornithologists is that coast lines, mountain chains, and especially the courses of the larger rivers and their tributaries form well-marked highways along which birds return to previous nesting sites. According to this theory, a bird breeding in northern Indiana would in its fall migration pass down the nearest little rivulet or creek to the Wabash River, thence to the Ohio, and reaching the Mississippi would follow its course to the Gulf of Mexico, and would use the same route reversed for the return trip in the spring. The fact is that each county in the Central States contains nesting birds which at the beginning of the fall migration scatter toward half the points of the compass; indeed, it would be safe to say all the points of the compass, as some young herons preface their regular journey south with a little pleasure trip to the unexplored north. In fall most of the migrant land birds breeding in New England move southwest in a line approximately parallel with the Allegheny Mountains, but we can not argue from this that the route is selected so that mountains will serve as a guide, because at this very time thousands of birds reared in Indiana, Illinois, and to the northwestward are crossing these mountains at right angles to visit South Carolina and Georgia. This is shown specifically in the case of the palm warblers. They winter in the Gulf States from Louisiana eastward and throughout the Greater Antilles to Porto Rico; they nest in Canada from the Mackenzie Valley to Newfoundland. To migrate according to the "lay of the land," the Louisiana palm warblers should follow up the broad open highway of the Mississippi River to its source and go thence to their breeding grounds, while the warblers of the Antilles should use the Allegheny Mountains as a guide. As a matter of fact, the Louisiana birds nest in Labrador and those from the Antilles cut diagonally across the United States to summer in central Canada. These two routes of palm warblers

cross each other in Georgia at approximately right angles. It is possible to trace the routes of the palm warblers because those nesting to the east of Hudson Bay differ enough in color from those nesting farther west to be readily distinguished even in their winter dress.

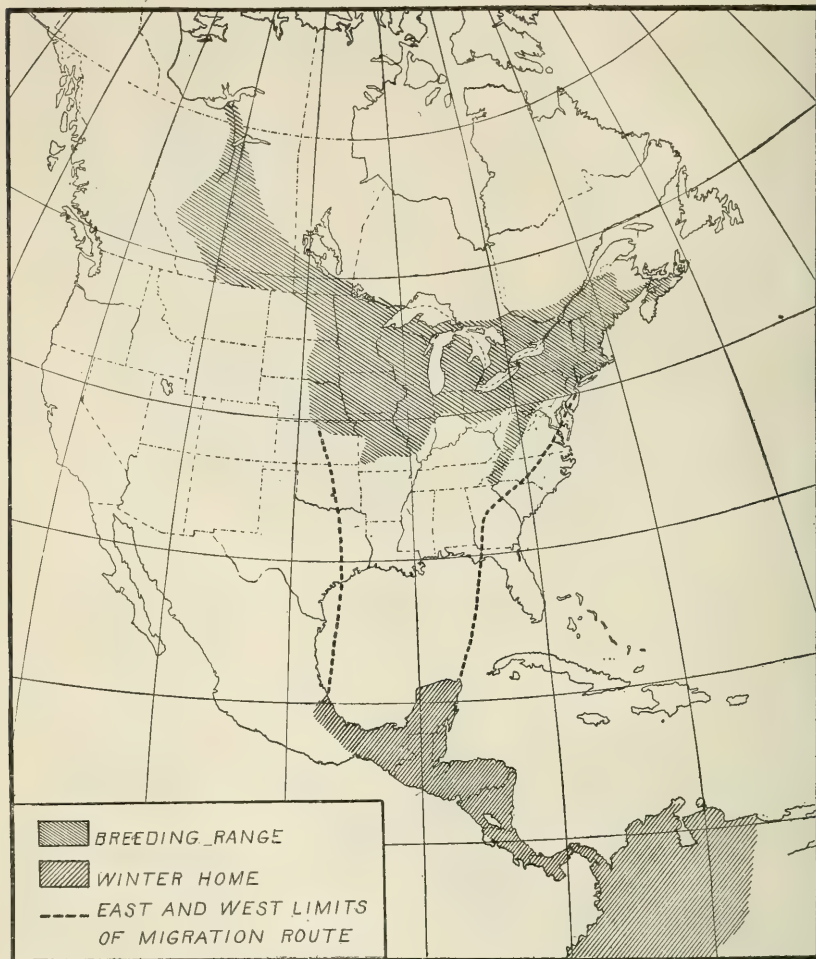


FIG. 13.—Distribution and migration of the rose-breasted grosbeak (*Zamelodia ludoviciana*). An example of a narrow migration route. The breeding range has an east and west width of 2,500 miles, while in migration the birds converge until they leave the United States along a line of the Gulf coast only 800 miles wide. (See p. 24.) The opposite of this (a wide migration route) is shown by the distribution map of the redstart, fig. 12.

It must always be remembered, however, that from a common ancestry these two groups of palm warblers came to differ in appearance because they gradually evolved differences in breeding grounds and in migration routes and not that they chose different routes because they were subspecifically different.

The truth seems to be that birds pay little attention to natural physical highways except when large bodies of water force them to deviate from the desired course. Food is the principal factor in determining migration routes, and in general the course between summer and winter homes is as straight as the birds can find and still have an abundance of food at each stopping place.

MIGRATION AND MOLTING.

It is interesting to note the relation between migration and molting. Most birds care for their young until old enough to look out for themselves, then molt, and when the new feathers are grown start on their southward journey in their new suits of clothes. But the birds that nest beyond the Arctic Circle have too short a summer to permit such leisurely movements. They begin their migration as soon as possible after the young are out of the nest and molt en route. Indeed, these Arctic breeders are so pressed for time that many of them do their courting during the period of spring migration and arrive at the breeding grounds already paired and ready for nest building, while many a robin and bluebird in the middle Mississippi Valley has been in the neighborhood of the nesting site a full month before it carries the first straw of construction.

Various peculiar changes of plumage are presented by certain species during migration. The young golden plover are white breasted as they fly over the Atlantic Ocean in fall. This has given place to jet black as they cross the Gulf of Mexico in spring. The bobolink (Pl. I) goes south in fall obscurely marked with buff and olive; he returns next spring the well-known black and white denizen of the marshes. The scarlet tanager (Pl. IV) performs his fall migration in a suit of uniform greenish yellow known to only a small number of his human friends, who welcome him as an old acquaintance when he returns the next spring in his striking black and scarlet.

CASUALTIES DURING MIGRATION.

Migration is a season full of peril for myriads of winged travelers, especially for those that cross large bodies of water. Some of the water birds making long voyages can rest on the waves if overtaken by storms, but for the luckless warbler or sparrow whose feathers become water-soaked an ocean grave is inevitable. Nor are such accidents infrequent. A few years ago on Lake Michigan a storm during spring migration forced to the waves numerous victims, as evidenced by many subsequently drifting ashore. If such mortality could occur on a lake less than 100 miles wide, how much more likely even a greater disaster attending a flight across the Gulf of Mexico. Such a catastrophe was once witnessed from the deck of a vessel 30 miles off

the mouth of the Mississippi River. Large numbers of migrating birds, mostly warblers, had accomplished nine-tenths of their long flight and were nearing land, when caught by a "norther," with which most of them were unable to contend, and falling into the Gulf they were drowned by hundreds.

During migration birds are peculiarly liable to destruction by striking high objects. The Washington Monument, at the National Capital, has witnessed the death of many little migrants; on a single morning in the spring of 1902 nearly 150 lifeless bodies were strewn

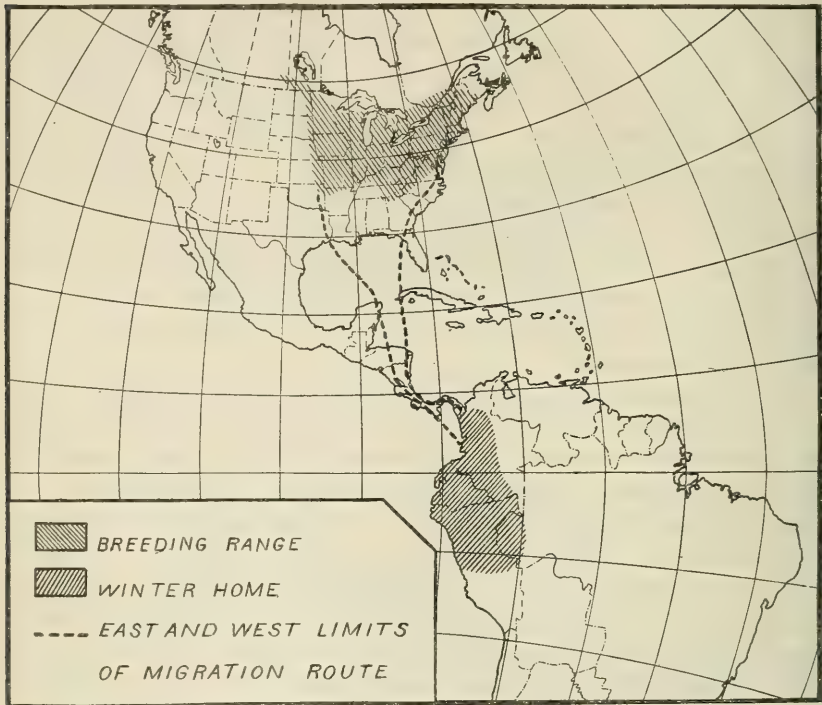


FIG. 14.—Distribution and migration of the scarlet tanager (*Piranga erythromelas*). An example of an extremely narrow migration route. The breeding range has an east and west extension of 1,900 miles. The migrating lines converge until in southern Central America the limits are not more than 100 miles apart. (See p. 25.) For a less narrow and a wide migration route see figs. 13 and 12, respectively.

around its base. As long as the torch in the Bartholdi Statue of Liberty in New York Harbor was kept lighted the sacrifice of bird life it caused was enormous, even reaching a maximum of 700 birds in a month.

Every spring the lights of the lighthouses along the coast lure to destruction myriads of birds en route from their winter homes in the South to their summer nesting places in the North. Every fall a still greater death toll is exacted when the return journey is made. Lighthouses are scattered every few miles along the more than 3,000 miles

of coast line, but two lighthouses, Fowey Rocks and Sombbrero Key, cause far more bird tragedies than any others. The reason is twofold—their geographic position and the character of their lights. Both lights are situated at the southern end of Florida, where countless thousands of birds pass each year to and from Cuba; and both are lights of the first magnitude on towers 100–140 feet high. Fowey Rocks has a fixed white light, the deadliest of all. A flashing light frightens birds away and a red light is avoided by them as would be a danger signal, but a steady white light looming out of the mist or darkness seems like a magnet drawing the wanderers to destruction. Coming from any direction they veer around to the leeward side and then flying against the wind strike the glass, or more often exhaust themselves like moths fluttering in and out of the bewildering rays.

ARE BIRDS EXHAUSTED BY LONG FLIGHT?

During the spring migration of 1903 two experienced ornithologists spent the entire season on the coast of northwestern Florida, visiting every sort of bird haunt. They were eminently successful in the long list of species identified, but their enumeration is still more remarkable for what it does not contain. About 25 species of the smaller land birds of the Eastern States were not seen, including a dozen common species. Among these latter were the chat, the redstart, and the indigo bunting, three species abundant throughout the whole region to the northward. The explanation of their absence from the list seems to be that these birds, on crossing the Gulf of Mexico, flew far inland before alighting and thus passed over the observers. This would seem to disprove the popular belief that birds under ordinary circumstances find the ocean flight excessively wearisome, and that after laboring with tired pinions across the seemingly endless wastes they sink exhausted on reaching terra firma. The truth seems to be that, endowed by nature with wonderful powers of aerial locomotion, many birds under normal conditions not only cross the Gulf of Mexico at its widest point but even pass without pause over the low swampy coastal plain to the higher territory beyond.

So little averse are birds to an ocean flight that many fly from eastern Texas to the Gulf coast of southern Mexico (see fig. 2, route 5), though this 400 miles of water journey hardly shortens the distance of travel by an hour's flight. Thus birds avoid the hot, treeless plains and scant provender of southern Texas by a direct flight from the moist, insect-teeming forests of northern Texas to a similar country in southern Mexico.

That birds are not exhausted by their long flights will be evident upon consideration of the origin of these protracted journeys. All migratory movements must have begun with changes of location

which were very slight, whether over land or water. From this short migration benefit accrued to individuals or to their posterity. Migration became a fixed habit, and the distance covered gradually—very gradually—increased as each succeeding extension proved advantageous. It is not to be supposed that every attempted

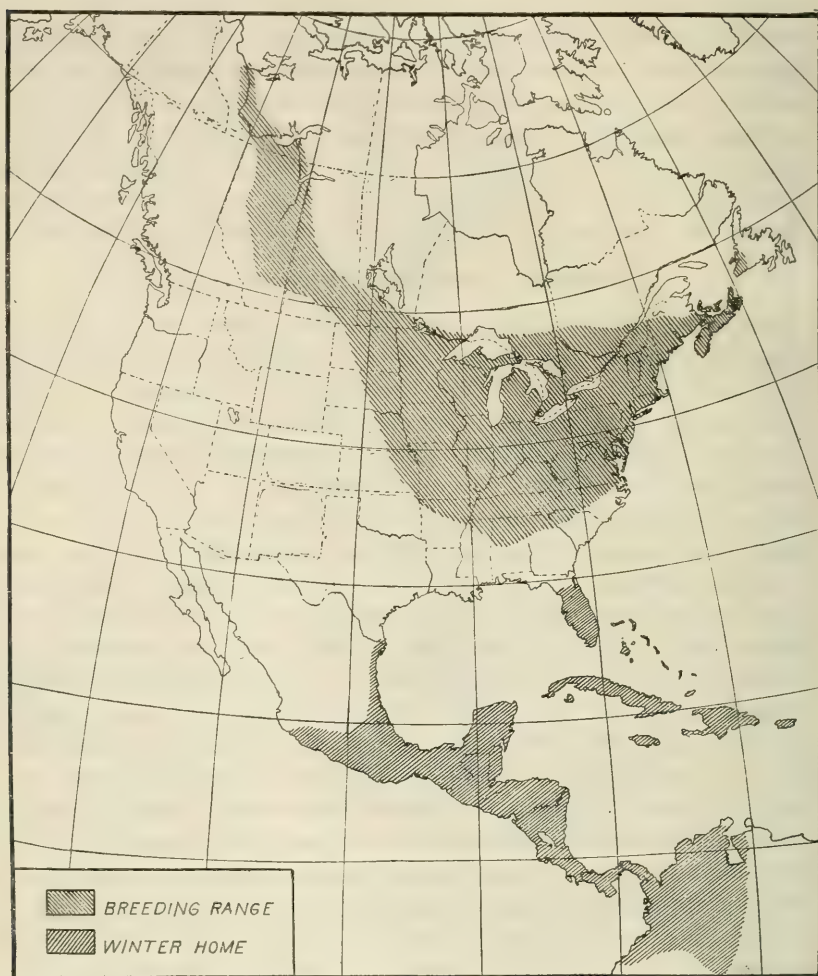


FIG. 15.—Summer and winter homes of the black-and-white warbler (*Mniotilta varia*). A very slow migrant. The isochronal lines of migration indicating the rate of speed are shown in figure 16. (See p. 25.)

extension was successful; in fact, it is more probable that only a small part of the experimental pioneer routes were permanently adopted. Moreover, it must be borne in mind that the time occupied in the establishment of present migration habits and routes is to be measured by geologic ages, and there is no reason to suppose that changes took place during these ages any faster than they do

now. Therefore when one of these experimental routes proved detrimental it was abandoned.

In this connection it may be well to consider the actual amount of energy expended by birds in their migratory flights. Both the soaring and the sailing of birds show that they are proficient in the use of several factors in the art of flying that have not yet been mastered either in principle or practice by the most skillful of modern aviators. A vulture or a crane, after a few preliminary wing beats, sets its wings and mounts in wide sweeping circles to a great height, overcoming gravity with no exertion apparent to human vision even when assisted by the most powerful telescopes. The Carolina rail, or sora, has small, short wings apparently ill adapted to protracted flight, and ordinarily when forced to fly does so reluctantly and alights as soon as possible. It flies with such awkwardness and apparently becomes so quickly exhausted that at least one writer has been led to infer that most of its migration must be made on foot; the facts are, however, that the Carolina rail has one of the longest migration routes of the whole rail family and easily crosses the wide reaches of the Caribbean Sea. The humming bird, smallest of all birds, crosses the Gulf of Mexico, flying over 500 miles in a single night. As already noted, the golden plover flies from Nova Scotia to South America, and in fair weather makes the whole distance of 2,400 miles without a stop, probably requiring nearly if not quite 48 hours for the trip.

Here is an aerial machine that is far more economical of fuel—i. e., of energy—than the best aeroplane yet invented. The to-and-fro motion of the bird's wing appears to be an uneconomical way of applying power, since all the force required to bring the wing forward for the beginning of the stroke is not only wasted, but more than wasted, as it largely increases the air friction and retards the speed. On the other hand, the screw propeller of the aeroplane has no lost motion. Yet less than 2 ounces of fuel in the shape of body fat suffice to force the bird at a high rate of speed over that 2,400-mile course. A thousand-pound aeroplane, if as economical of fuel, would consume in a 20-mile flight not the gallon of gasoline required by the best machines but only a single pint.

EVOLUTION OF MIGRATION ROUTES.

It has already been stated that each of the present migration routes, however long, has probably been of slow growth from an originally short flight. In the case of many routes it is easy to trace the probable steps in evolution. Thus the route across the Gulf of Mexico, from the mouth of the Mississippi to Campeche, at the end of the glacial era was undoubtedly a trip by land through Texas. As the land now the Eastern States arose from the ocean or

was freed from the overlying ice cap, the tendency would be for the migration route at its northern end to turn and be extended eastward to enter the new and as yet uncrowded districts. The route at this stage would be a half circle, and a tendency would soon develop to shorten some of the curve through Texas by a short flight over the western end of the Gulf of Mexico. This short flight would

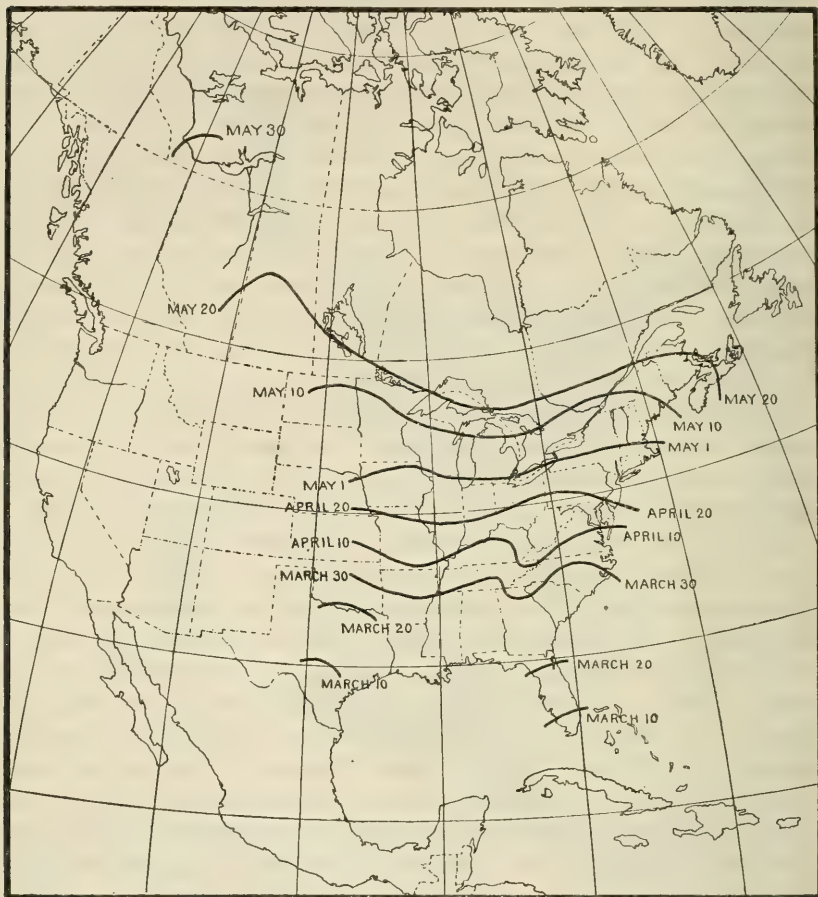


FIG. 16.—Isochronal migration lines of the black-and-white warbler (*Mniotilta varia*). An example of a slow and uniform migration. Isochronal lines indicating the advance of the warbler during each 10-day period of spring show an average speed of about 20 miles a day in March in Florida and about 25 miles a day for the whole trip to southeastern Canada. (See p. 25.) The opposite (a rapid migration) is shown by the gray-cheeked thrush (fig. 17).

gradually be lengthened and its points of arrival and departure at the mainland carried eastward until eventually the curve would be replaced by a straight flight across the Gulf.

Some migration routes have been so recently developed that they still plainly show their origin. The red-eyed vireo, a striking example, is a woodland bird and as such is essentially an inhabitant of the

States east of the Great Plains; but an arm of the breeding range extends northwestward to the Pacific coast in British Columbia (see fig. 18). It is evident that this is a late extension of the range, that it has taken place by a westward movement from the lower Missouri Valley section, and that the nesting birds of Washington and British Columbia retrace in spring and fall the general route by which they originally invaded the country.

The origin of this vireo's route is also indicated by the isochronal lines shown in figure 19. On March 20 the vanguard is just entering the United States from the winter home in South America. Northward progression is fairly uniform for the next 5 of the 10-day periods, carrying the birds to eastern Nebraska, southern Michigan, and southern New England. But then a change becomes evident. The eastern birds continue their lines of flight and pass almost directly to their summer homes. Some of the western-born individuals, however, begin to turn at a wide angle from their previous course and proceed on a long northwestward slant to the Pacific. It is especially to be noted that as these individuals change their course they quicken their speed until they travel on the average more than twice as far a day as their eastern brethren.

In the case of the bobolink the evolution of a new extension of the migration route is now occurring before our very eyes. By nature a lover of damp meadows, the bobolink was formerly cut off from the Western States by the intervening arid region. But with the advent of irrigation and the bringing of large areas under cultivation, little colonies of nesting bobolinks are beginning to appear here and there almost to the Pacific. Some of these colonies are shown by encircled areas on the map in figure 1, and the probability is that the not distant future will witness a large increase in the number of bobolinks west of the Rocky Mountains.

NORMAL AND ABNORMAL MIGRATION.

The relative position of the northern and southern groups of individuals of a species during the two yearly migrations is one of the obscure points that late investigations help to elucidate. The supposition is that in the case of species which adopt what may be called normal fall migration, birds which nest farthest south migrate first and proceed to the southern end of the winter range; those that breed in the middle districts migrate next and occupy the middle of the winter range; and, finally, those of the northern part of the breeding range migrate last and remain farthest north for the winter. In other words, the migration is a southward movement of the whole species during which the different groups of individuals or colonies retain in general their relative positions. This has been commonly believed, but only of late has it been clearly proved for any particular species.

An example or two will make this clear. The black-and-white warbler breeds from South Carolina to New Brunswick (see fig. 15). In the southern part of its range it nests in April. New Brunswick, however, is scarcely reached by the earliest birds before the middle of May (see fig. 16), as the species occupies about 50 days in crossing

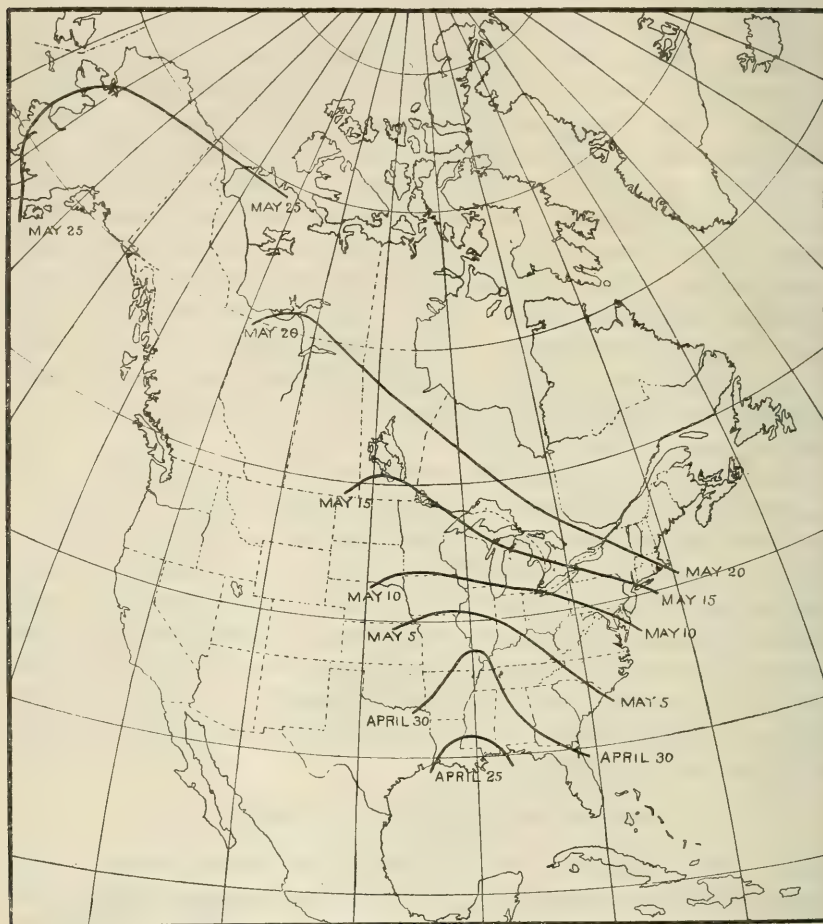


FIG. 17.—Isochronal migration lines of the gray-cheeked thrush (*Hylocichla aliciae*). An example of rapid migration. The whole 4,000 miles from Louisiana to Alaska is passed over in about 30 days, or about 130 miles per day. The last part of the route the speed is several times what it is in the central Mississippi Valley. (See p. 27.) For an example of the opposite, a slow migration, see the black-and-white warbler (fig. 16).

the breeding range. It is probable that 60 days is about the shortest possible time in which such a bird could build a nest, rear its young, molt, and be ready for the return journey; and if so, then no New Brunswick black-and-white warbler is ready to start south before the middle of July, and 50 days for the trip would bring the earliest migrants to the Gulf States in September. Yet both old birds and

young of the year have been seen by the middle of July at Key West, Fla., 500 miles south of the breeding range; on August 10 in Costa Rica; and on August 21 on the northern coast of South America. These dates point to the conclusion that early migrants south of the United States could not have been birds from the northern part of the range, but must have been those from the southern part.

Black-throated blue warblers reach Cuba in fall just about the time other migrants of the species appear in North Carolina. The inference is that the arrivals in Cuba are the birds that nested in the southern Alleghenies, while those appearing in North Carolina are from the latitude of northern New England or beyond. Redstarts and summer warblers arrive on the northern coast of South America so early (August 27 to September 2) as to indicate that they represent the southern breeding birds. Indeed, these representatives of the species are seen in South America just about the time the earliest of the northern breeding birds reach Florida.

Recent investigations have shown also that many species of birds do not follow this "normal" order of migration. The most southern-bred Maryland yellow-throats are almost nonmigratory, residing throughout the year in Florida; those breeding in the middle districts migrate only a short distance; while those from Newfoundland go to the West Indies, passing directly over the winter home of their fellows in the South. The red-winged blackbirds of the middle of the range in northern Texas are almost stationary, but are joined in winter by migrant red-wings from the remote Mackenzie Valley. The palm warblers of the interior of Canada in the course of their 3,000-mile journey from Great Slave Lake to Cuba pass through the Gulf States early in October. After the bulk have passed, the palm warblers of the Northeastern Provinces come slowly to the Gulf States and settle there for the winter, content with only a 1,500-mile trip. Some of the blackpoll warblers that pass in spring through Florida proceed northeast 1,000 miles to breed in northern New England, while others, traveling northwest more than 3,000 miles, summer in Alaska. Among the Maryland yellow-throats nesting in western Pennsylvania are undoubtedly individuals that during the winter are scattered in the Gulf States, the West Indies, and even Central America. These examples show that no invariable rule, law, or custom exists in regard to the direction or distance of migration.

The winter distribution can not certainly be determined from the summer home, nor does it positively indicate that home. The statement can be made still stronger. Each species is composed of many small groups, each of which in regard to summer and winter home and route of migration is a law unto itself, and the knowledge of these facts with regard to one group offers little or no basis for

judgment in regard to members of other groups. Thus, although a certain general tendency is observable, each species presents a separate problem, to be solved for the most part only by patient, painstaking observation.

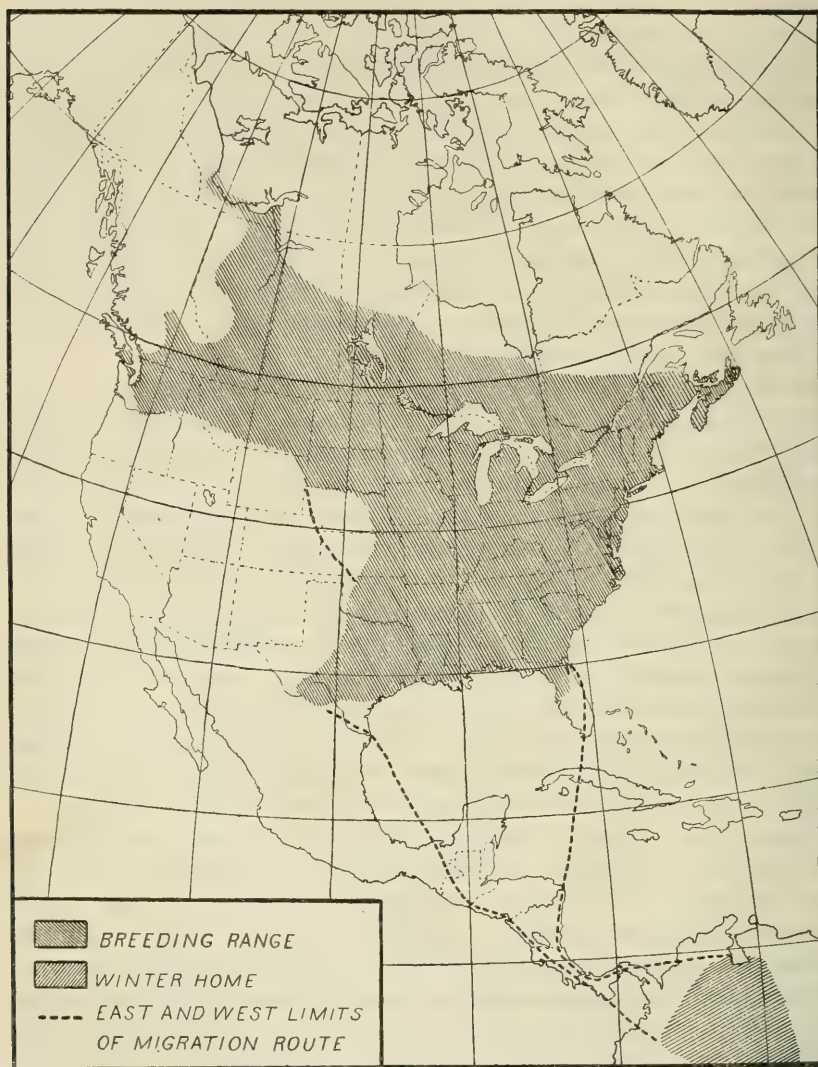


FIG. 18.—Distribution and migration of the red-eyed vireo (*Vireosylva olivacea*). An example of a lately extended breeding range and migration route. It is evident that the species has only recently invaded Washington by an extension almost due west from the northern Mississippi Valley, and that it still migrates spring and fall along the route originally traversed in this extension. (See p. 37 and also fig. 19.)

RELATIVE POSITION DURING MIGRATION.

Spring migration has its own special features, and no such synchronous movement then occurs as has been described as "normal

migration" in fall. With many birds, probably the majority of land birds, the first individuals of a species to appear at a given locality are old birds that nested there the previous year; these are followed by others that nested in the region just to the north; and the last to appear are those whose homes are in the most northern part of the breeding range. The above statement applies only to old birds; in what order or at what time young of the previous year migrate has not yet been discovered. If, then, for any species, the southern-nesting birds lead the van in both fall and spring migrations and the rear guard in each case is composed of northern-breeding birds, it follows that some time between October and April a transposal of their relative positions occurs, and that the more southern birds pass over those whose migration farther north is delayed by winter still holding sway in their summer dominions. Just when and where this transposition occurs is a problem of migration reserved for future solution. Nor is it yet settled whether northern-bred birds remain strictly within their winter range until after their more southern congeners have passed by, or whether they begin an early migration so slowly as soon to be overtaken and passed by their more impetuous cousins.

Still later in spring another transposition occurs. The northern birds pass across the southern part of the breeding range, where the southernmost birds are already busy with their domestic duties. Spring migration seems, therefore, to be for most species a game of leapfrog, the southern birds first passing the northern and the northern passing them in turn.

RELATION BETWEEN MIGRATION AND TEMPERATURE.

The Canada goose is typical of what may be called regular migration. This bird fulfills the popular notion of bird migration, i. e., it moves northward in spring as soon as the loosening of winter's fetters offers open water and a possibility of food. It continues its progress at the same rate as spring, appearing at its most northern breeding grounds at the earliest possible moment. The isotherm of 35° F. (see fig. 20) seems to be the governing factor in the rate of spring migration of the Canada goose and, as shown on the map, the isotherm and the vanguard of the geese are close traveling companions throughout the entire route. Moreover, the isochronal lines representing the position of the van at various times are approximately east-and-west lines during the whole migration period.

But this so-called regular migration is performed by a very small percentage of species, the great majority choosing exactly the opposite course—to remain in their winter homes until spring is far advanced and then reach their breeding grounds by a migration much more rapid than the northward advance of the season. The summer

warbler is a good example of this usual habit. Some summer warblers that return to the Great Slave Lake region to breed after spending the winter in Central and South America arrive at their nesting grounds when the average daily temperature is about 47°F . According to the movements of the Canada goose, these summer warblers might be expected to pass up the Mississippi Valley and on to their

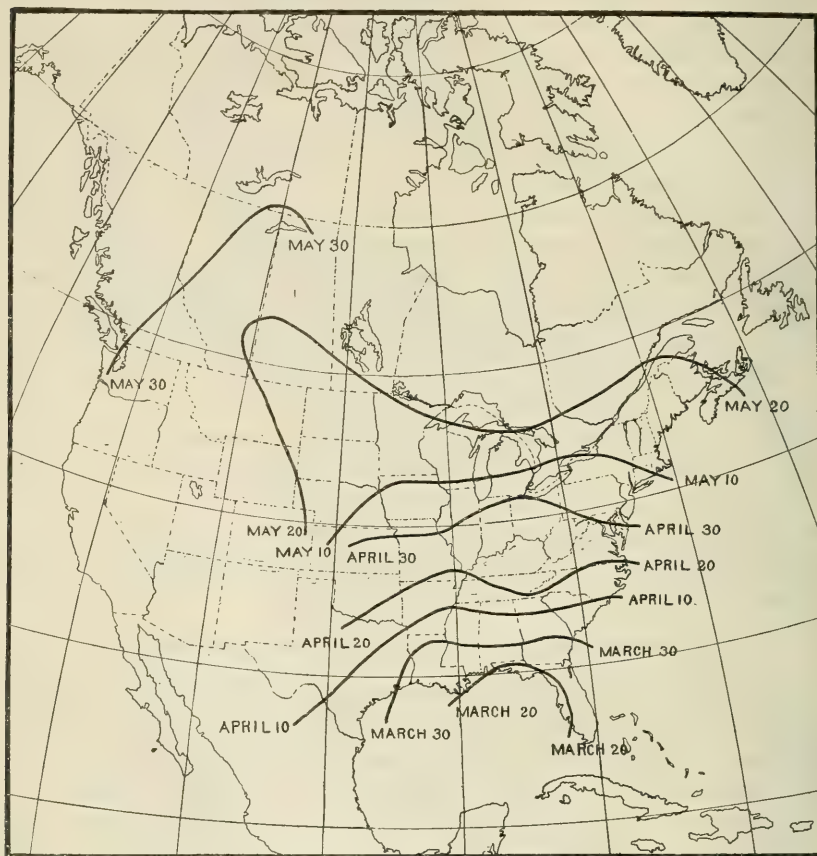


FIG. 19.—Isochronal migration lines of the red-eyed vireo (*Vireosylva olivacea*). An example of a recently extended migration route. The birds which are to nest in New England advance along the Atlantic coast in approximately a straight line and at a fairly uniform speed, while those which are to nest in Washington advance up the Mississippi Valley at about the same speed until eastern Nebraska is reached, when they turn sharply to the northwest and more than double their speed as they journey along this recently extended route to the far northwest. (See p. 37 and also fig. 18.)

summer homes at the same time as the northward-moving temperature of 47°F . But if this were so they would never leave the United States, for the average temperature of the coldest month of the year at New Orleans is 54°F . As a matter of fact, the summer warblers of Great Slave Lake are probably too well content with the warm, humid, insect-laden air of the south to brave the arctic blasts before

necessity compels. They linger in the Tropics so late that when they reach New Orleans, April 5, an average temperature of 65° F. awaits them. They now hasten. Traveling north much faster than the spring does, they cover 1,000 miles in a month and find in southern Minnesota a temperature of 55° F. In central Manitoba the average temperature they meet is 52° F., and when they arrive late in May at Great Slave Lake they have gained 5 degrees more on the season. Thus during the whole trip of 2,500 miles from New Orleans to Great Slave Lake these birds are continually meeting colder weather. So fast do they migrate that in the 15 days from May 11 to 25 they traverse a district that spring requires 35 days to cross. This outstripping of spring is habitual with all species that leave the United States for the winter and also with most northern birds that winter in the Gulf States. Careful examination of migration records of each species of the Mississippi Valley shows only six exceptions—Canada goose, mallard, pintail, common crow, red-winged blackbird, and robin.

The robin as a species migrates north more slowly than the opening of the season; it occupies 78 days for its trip of 3,000 miles from Iowa to Alaska, while spring covers the distance in 68 days. But it does not follow that any individual bird moves northward at this leisurely pace. The first robins that reach a given locality in spring are likely to remain there to nest, and the advance of the migration lines must await the arrival of other birds from farther south. Therefore each robin undoubtedly migrates at a faster rate than the apparent movement of the species as a whole and does not fall behind the advancing season. This is true of most if not all of the other seemingly slow migrants. Late and rapid journeys of this kind offer certain advantages; fewer storms are encountered, the mortality rate is lowered, food is more plentiful along the way, and the birds reach the nesting site full of energy and in good condition to assume the cares and labors of house building and brood raising.

An extreme example of a late and rapid migration is that of the black-poll warbler (see fig. 5). The birds enter the United States in southern Florida April 20, when the average temperature there is 72° F. Ten days later the van has reached the central Mississippi Valley, where the temperature is 60° F., and the birds continue to advance faster than the progress of spring until at the time they reach their Alaska breeding grounds on May 30 they find there an average temperature of only 45° F.

VARIATIONS IN SPEED OF MIGRATION.

The immense variation in the speed with which migrants travel different parts of the broad bird highway extending from the Gulf to the Arctic Ocean by way of the Mississippi and Mackenzie Valleys is a recent determination of special interest. The black-poll warbler

furnishes one of the best examples (see fig. 5). Wintering in north-central South America and migrating in April across the West Indies to Florida, some individuals pass on northwest to the Mississippi Valley, north to Manitoba, northwest to the valley of the Mackenzie, and thence almost due west to western Alaska. From the Gulf of Mexico to Minnesota a fairly uniform average speed of 30 to 35 miles a day is maintained; southern Indiana and Missouri are reached the first week in May, southern Iowa early in the second week, and southern Minnesota is entered by the middle of the month. Then

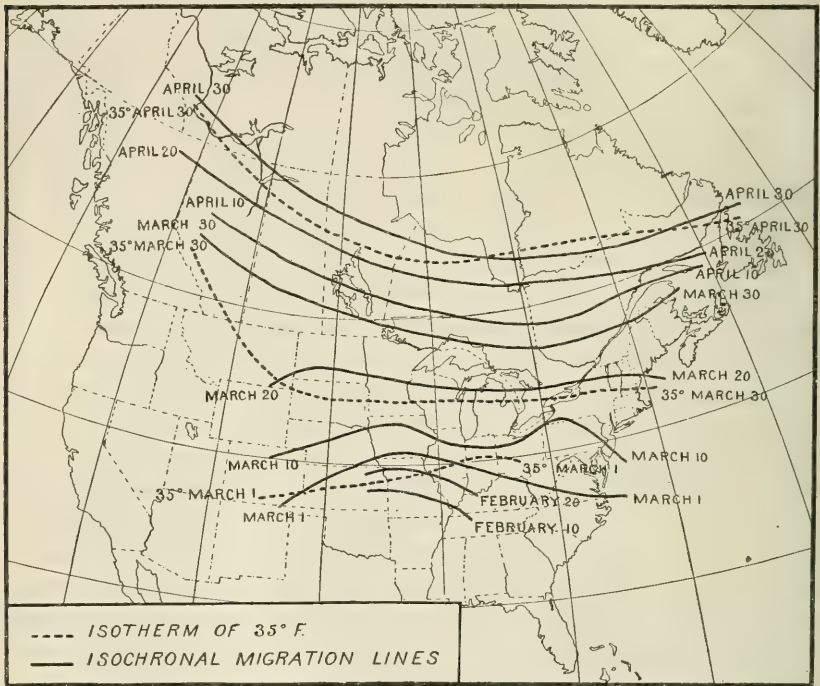


FIG. 20.—Migration of the Canada goose (*Branta canadensis*). An example of migration keeping pace with the advance of spring. The earliest Canada geese arrive in central Illinois when the average temperature is about 35° F., and they reach their most northern breeding grounds at about the same temperature, having advanced northward at approximately the same rate as the advance of spring. (See p. 41.)

comes a "spurt"; within another week the black-polls appear in the central part of the Mackenzie Valley, and the following week they arrive in northwestern Alaska, many individuals undoubtedly averaging more than 200 miles a day during the latter part of the journey. Thirty days are thus occupied in traveling the 1,000 miles from the Gulf of Mexico north to southern Minnesota, and scarcely half that time in traversing the remaining 2,500 miles northwest to Alaska. The directions of migration are emphasized because the change of direction is intimately connected with the great increase of speed, as will be explained.

A similar increase of speed is shown by many other species. The average speed of migration from New Orleans to southern Minnesota for all species is close to 23 miles a day. Sixteen species maintain a daily average of 40 miles from southern Minnesota to southern Manitoba, and from this point 12 species travel to Lake Athabaska at an average speed of 72 miles a day, 5 others to Great Slave Lake at 116 miles a day, and 5 more to Alaska at 150 miles a day.

The reason for these remarkable differences is very simple: The speed increases as the birds move northward because the advance of the season is more rapid in the northern interior than on and near the southern coast. The farther removed a district is from the ocean the greater the extremes of its temperature. At New Orleans the average daily temperature of January is 54° F., and that of July is 82° F., while at Winnipeg, Manitoba, the corresponding average temperatures are: January, -7° F.; July, 66° F. Hence during the period the temperature at New Orleans is rising 28 degrees, that at Winnipeg rises 73 degrees. Consequently as a given isotherm moves north during spring in the Mississippi Valley it continually increases its rate of advance. The isotherm of 35° F., corresponding to the commencement of spring migration, advances north at the rate of 3 miles a day from January 15 to February 15, 10 miles daily during the next month, and 20 miles daily during the following month.

But an additional explanation must be sought for the wonderfully quickened speed with which birds pass northwestward from Minnesota to the Mackenzie Valley. Along the eastern foothills of the Rocky Mountains isotherms travel north faster than at corresponding latitudes farther east. From February 15 to March 15 the isotherm of 35° F. (the line of spring) passes along the foothills from New Mexico to northern Colorado at the rate of 12 miles a day. During the next month, under the influence of the Chinook winds, its rate of northward progress is increased to 40 miles a day, so that by April 15 it has reached Lake Athabaska. Spring has come with a rush in this western interior country. The result is that during the height of the migration season, from the middle of April to the middle of June, the southern end of the Mackenzie in Saskatchewan has just about the same temperature as the Lake Superior region 700 miles farther south.

These conditions, coupled with the diagonal course of birds across this region of fast-moving spring, necessarily exert a powerful influence on bird migration. The robin's average temperature of migration is 35° F.; that is, the bird puts in an appearance soon after snow begins to melt and streams to open, but before vegetation has made any marked advance. These conditions occur in the central Mississippi Valley about the middle of February, and it is the first of March before spring and the robins cross northern Missouri and arrive

together in southern Iowa. Thence a whole month is consumed by the birds in their slow progress (13 miles a day) to central Minnesota. Their pace then quickens to keep up with the northward rush of spring, and another 10 days at doubled speed brings them to southern Canada. Here they must make an important choice. To the north and northeast lies a land that awakens slowly from its winter's sleep, and where the sun must wage a protracted warfare against the cold of the ice masses in Lake Superior and Hudson Bay. To the northwest stretches a less forbidding region already quickening under the influence of the Chinook winds.

Most of the robins from Missouri that pass through western Minnesota elect to turn to the northwest, and now they must not only keep pace with the rapidly advancing season but must do so on a long-drawn diagonal. Their daily average rises to 50 miles (four times that in southern Iowa) and later, when the course of the birds bound for western Alaska becomes nearly due west, the rate increases to 70 miles a day—more than six times the speed with which the journey began. The Alaska-breeding robins are the only ones that develop high speed. Robins bound for Newfoundland move leisurely along the Atlantic coast at the proverbially slow rate of the oncoming of spring in New England, and, scarcely exceeding 17 miles a day, they finally arrive at their destination the first week in May, when their Alaska-bound relatives are already 1,200 miles farther north.

An interesting migration route is that of the robins nesting in southern Alberta, which arrive too early to have come from the south and southeast; hence they must have come from the southwest, though this route has necessitated their crossing the main range of the Rockies while the mountains were still in the grasp of winter. Robins remain all winter on the Pacific coast, north to southwestern British Columbia, which has about the same winter temperature as St. Louis, 700 miles farther south. Hence the wintering robins of British Columbia are already far north at the advent of spring and do not need any hurried migration to reach Alberta on time, so that they average only 8 miles a day, the slowest rate for the species. It may fairly be asked, How do we know that the Alaska robins have come all this long distance from the central Mississippi Valley, instead of the far shorter distance from British Columbia? It happens that the robins of the two sides of the continent slightly differ in color and in pattern of coloration. Birds of the western style are not known north of southwestern Saskatchewan, central British Columbia, and southeastern Alaska, while the whole country to the northward is occupied by birds whose characteristics prove that they came from the southeast.

It does not necessarily follow that any individual bird makes all these changes in its speed of migration. The flight of the individual can not be traced or timed under the present system of obtaining records, and in the above statements it is meant that the general advance of the van of the birds is marked by these great changes in speed. It is quite likely that the first robins which reach central Minnesota at an average speed of 13 miles a day stop there and nest, and it is possible that those which continue the advance to southern Mackenzie at an average speed of 40 miles a day are individuals that have waited later in the winter home and have covered the whole distance at the higher rate.

That individual birds do increase their daily rate of progress as they proceed northward seems probable from the records of the gray-cheeked thrush (see fig. 17). The earliest migrants of this species travel from southern Louisiana to northern Iowa (1,000 miles) in about 15 days, or over 60 miles a day. As at this time they are passing over a country in which they do not breed, there is no reason to infer that the same birds do not keep continually in the lead. Hence 60 miles a day may be considered the actual average speed of individuals forming the van of this species. Two weeks later the earliest gray-cheeked thrushes appear in northwestern Alaska, 3,000 miles from Iowa, and it seems unreasonable not to conclude that the same birds that averaged about 60 miles a day as they moved north in the lower Mississippi Valley have greatly increased this speed as they continued their journey northwestward and finally westward to Alaska.

THE UNKNOWN.

Interest in bird migration goes back to a remote period; marvelous as were the tales of spring and fall movements of birds, as spun by early observers, yet hardly less incredible are the ascertained facts. Much has been learned about bird migration in these latter days, but much yet remains to be learned, and the following is one of the most curious and interesting of the unsolved problems. The chimney swift is one of the most abundant and best-known birds of eastern United States. With troops of fledglings catching their winged prey as they go and lodging by night in tall chimneys, the flocks drift slowly south joining with other bands, until on the northern coast of the Gulf of Mexico they become an innumerable host. Then they disappear. Did they drop into the water or hibernate in the mud, as was believed of old, their obliteration could not be more complete. In the last week in March a joyful twittering far overhead announces their return to the Gulf coast, but their hiding place during the intervening five months is still the swift's secret.

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No. 186



Contribution from the Bureau of Entomology, L. O. Howard, Chief, and the
Bureau of Plant Industry, Wm. A. Taylor, Chief.

February 27, 1915.

A METHOD OF FUMIGATING SEED.¹

By E. R. SASSCER, *Chief Inspector, Federal Horticultural Board*, and LON A. HAWKINS,
Plant Physiologist, Plant Physiological and Fermentation Investigations.

INTRODUCTION.

A perfectly reliable method of destroying insects present in seeds imported into this country, without injury to the seed, is much needed. The exclusion of insects by a careful selection of apparently uninfested seeds at the port of export is impracticable, because many injurious insects pass their larval and pupal stages and a portion of the adult stage inclosed within the seed and on this account might easily escape notice when the seeds were inspected. Furthermore, seeds are frequently received from localities where injurious insects are not well recognized, and, also, insects which are only slightly injurious in their native habitats occasionally become destructive pests when established in this country.

The ordinary methods of destroying insects in stored seeds, such as subjecting them to heat (with or without moisture), carbon bisulphid, and hydrocyanic acid in the presence of air, have been tried and found unsatisfactory for this purpose.

It occurred to the writers to create a partial vacuum in the container in which the seeds had been placed and fill the chamber with some gaseous insecticide, such as carbon bisulphid or hydrocyanic acid, in the belief that a much larger amount of gas might thus be forced into the crevices of the seeds and into the insect galleries than would be possible if the entrance of the gas were dependent upon diffusion under normal atmospheric pressure. This method was successfully used with a number of different kinds of seeds and insects, and a convenient chamber, described later, was devised for fumigation under reduced pressure.

¹This work was carried on in cooperation between the Federal Horticultural Board and the Office of Plant Physiological and Fermentation Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.

FUMIGATION CHAMBER.

The fumigation chamber (fig. 1 and fig. 2, *b*) is of iron tubing, 36 inches long by 12 inches in diameter. One end of this cylinder is permanently closed with a heavy iron cap (fig. 1, *a*). The other end is fitted with a flange and can be closed with a brass plate (fig. 1, *b*), which is held in place by clamps. One face of the plate is ground to fit the flange, which is also ground. A wide rubber gasket is placed between the two faces when the plate is clamped in position. The chamber is designed to lie with its longest axis in a horizontal position. On the side of the chamber intended to lie uppermost three openings are made, one being in the center and one at each end. The opening

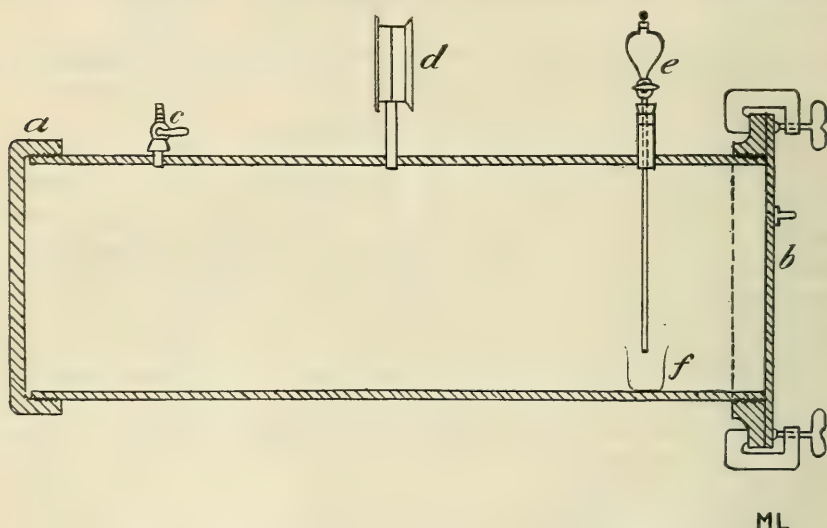


FIG. 1.—Diagram of fumigation chamber: *a*, Iron cap; *b*, brass plate clamped on end of chamber; *c*, gas cock for attaching suction hose; *d*, vacuum gauge; *e*, dropping funnel, by means of which the sulphuric acid is introduced into the chamber; *f*, beaker to contain cyanid.

near the capped end is fitted with a gas cock (fig. 1, *c*), so that the suction hose of a vacuum pump can be readily attached. A vacuum gauge, registering the decrease in pressure in units equivalent to inches of mercury, is placed in the center opening (fig. 1, *d*), while a tubulature is placed in the opening near the flange. The tubulature is closed with a perforated rubber stopper bearing a dropping funnel (fig. 1, *e*) so arranged that the bulb and stopcock are outside the chamber, while the tube extends down inside the chamber nearly to the bottom. The rubber stopper and dropping funnel can be readily removed when seeds or other material to be fumigated are placed in the chamber. An air pump, driven by a motor and capable of reducing the air pressure to the equivalent of about 0.05 of a millimeter of mercury, is used to secure an almost complete vacuum (fig. 2, *a*).

When this apparatus is used for fumigation, the seeds, contained in either a cloth bag or an open vessel, are placed in the chamber, and the requisite amount of sodium or potassium cyanid in a small beaker is so arranged that the neck of the dropping funnel extends down into the beaker (fig. 1, *f*). The cover is then clamped on and the chamber exhausted. In extracting the air from the chamber, the suction is continued until the gauge registers 30 inches or more—that is, the air in the chamber is exhausted until the pressure is the equivalent of some fraction of an inch of mercury. The suction is then cut off by means of the gas cock, and the required quantity of diluted acid, which has been previously placed in the bulb of the

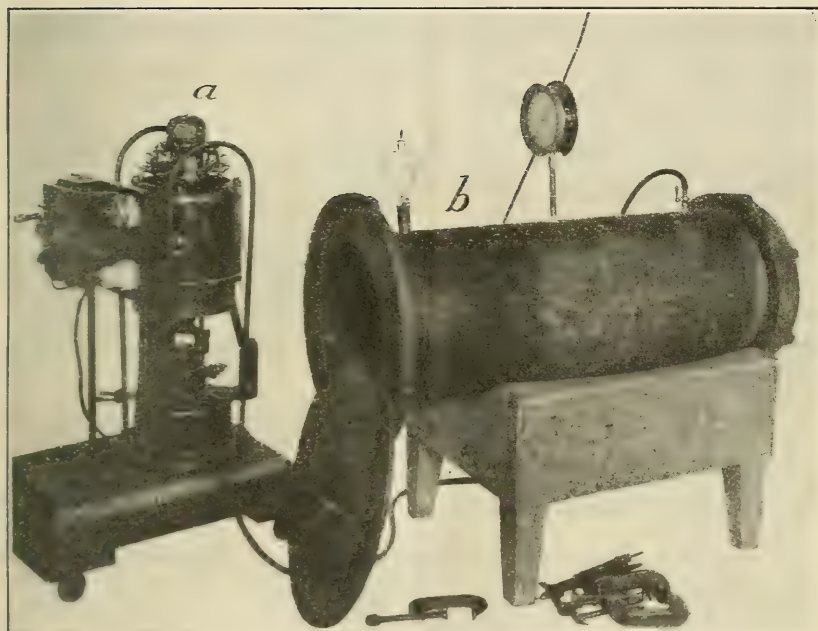


FIG. 2.—Air pump (*a*) and fumigation chamber (*b*) used in the experiments described in this bulletin.

dropping funnel, is allowed to flow slowly upon the cyanid in the beaker within the chamber. The hydrocyanic acid is thus prepared in the chamber and no trace can get out. After the seeds are exposed to the gas for the required time, the stopcock of the dropping funnel is opened to let the air into the chamber. As the discharge pipe of the air pump extends outside the building, the mixture of hydrocyanic acid and air can not escape into the room. As soon as convenient, the stopper and funnel are removed and, by means of the air pump, air is sucked through the chamber, thus washing the hydrocyanic acid out of the chamber before the cover is taken off and the seeds removed. In the experiments described

here the seeds were examined carefully at several different times to see whether all insects were killed. The viability of the seeds was then tested.

Part of the germination tests recorded in this paper were made by Mr. W. R. Lucas, of the Office of Foreign Seed and Plant Introduction, but in most cases tests with treated and untreated seeds were carried out by Mr. W. L. Goss, of the Seed Laboratory of the Bureau of Plant Industry.

In these experiments the duration of the exposure and the concentration of hydrocyanic acid were varied in order to determine the minimum exposure and concentration of hydrocyanic acid which would insure the death of all the infesting insects. It was also considered of interest to determine whether the seeds would be uninjured if exposed longer and with a higher concentration of the hydrocyanic acid than that necessary to kill the insects. The duration of the exposure and the amounts of sodium or potassium cyanid are given in the description of the experiments. The 1-1-2 formula was used for potassium cyanid and the 1-1½-2 formula for sodium cyanid.

The iron fumigation chamber already described was used in most of the experiments. In some of the preliminary work, however, desiccators or bell jars were used instead. The essentials of the method were the same in either case, and no description of these pieces of apparatus seems necessary.

EXPERIMENTS.

The summarized results of these experiments are here given in tabular form for comparison (Table I).

TABLE I.—Summary of experiments in fumigating against insects.

Material.	Infested with—	Kind of cyanid and amount used.	Time of exposure.	Result.	Germination test.
Avocado: 26 seeds.	One adult avocado weevil (<i>Heilipus lauri</i>).	Sodium cyanid, ½ gm., in desiccator.	Hrs. 1	Insect dead.....	22 out of 26 seeds germinated.
29 seeds.		do.....	½	.....	20 out of 29 seeds germinated; 21 out of 25 germinated in control test.
5 seeds.	Larvæ of avocado weevil (inclosed in a cotton-plugged vial) and broad-nosed grain weevil (<i>Caulophilus latinasus</i>).	do.....	½	All stages dead....	Seed cut up to determine mortality of insects and not planted.
20 seeds.	Larvæ of <i>Conotrachelus</i> sp. and broad-nosed grain weevil, all stages.	do.....	6	do.....	No germination.
Do.		do.....	12	do.....	Do.
6 seeds.		Sodium cyanid, 4 gms.	½	do.....	All seeds germinated.
10 seeds.		do.....	¼	No insects alive out of 50 examined of all stages.	Do.

TABLE I.—Summary of experiments in fumigating against insects—Continued.

Material.	Infested with—	Kind of cyanid and amount used.	Time of exposure.	Result.	Germination test.
Avocado: 7 seeds..	Larvæ of <i>Conotrachelus</i> sp. and broad-nosed grain weevil, all stages.	Sodium cyanid, 2 gms.	Hrs. $\frac{1}{4}$	1 grain-weevil larva alive.	Not planted.
6 seeds..	4 with all stages of broad-nosed grain weevil; 2 uninfested.	do	$\frac{1}{2}$	All stages dead....	3 seeds planted and all germinated.
10 seeds.	Scolytid.	do	$\frac{1}{2}$	Out of several hundred specimens 1 live adult was found.	Not planted.
Do.....	do	Sodium cyanid, 4 gms.	$\frac{1}{2}$	All stages dead....	Do.
Sorghum seed.	<i>Bruchus</i> sp.....	Sodium cyanid, 2 gms.	$\frac{1}{4}$	Insects alive	75.5 per cent germination; seed badly infested.
Do.....	<i>Bruchus</i> sp. and rice weevil (<i>Calandra oryza</i>).	Sodium cyanid, 4 gms.	$\frac{1}{2}$	All stages dead....	71 per cent germination; seed badly eaten.
Do.....	do	do	1	do	83 per cent germination.
Do.....	Rice weevil and cadelle (<i>Tenebroides mauritanicus</i>).	Sodium cyanid, $\frac{1}{2}$ gm., in desiccator.	$\frac{1}{2}$	do	Of four grades fumigated, the percentage of germination was as follows: 78.5; 86.5; 88; 83.
Do.....	do	do	1	do	Germination of fumigated seed superior to that of untreated seed.
Do.....	Rice weevil.....	Potassium cyanid, 2 gms.	30	do	Seed thoroughly infested with insects previous to fumigating and only 15 per cent germinated.
Bulbs.....	Bulb mite (<i>Rhizoglyphus hyacinthi</i>).	Sodium cyanid, $\frac{1}{2}$ gm., in desiccator.	1	All mites dead....	Bulbs thoroughly infested and unfit for planting.
Cotton seed.	Adults of the red grain beetle (<i>Cathartus gemellatus</i>).	Sodium cyanid, $\frac{1}{2}$ gms.	1	All insects dead....	Not planted.
<i>Gleditsia sinensis</i> in seed pods.	<i>Bruchus</i> sp. (adults)..	Sodium cyanid, 2 gms.	$\frac{1}{2}$	All insects dead, both in and out of seed pods.	Percentage of germination approximately the same with both fumigated and untreated seed.
Do.....	do	Sodium cyanid, 4 gms.	$\frac{1}{2}$	do	Do.
<i>Phaseolus vulgaris</i> .	<i>Bruchus</i> sp.....	Sodium cyanid, $\frac{1}{2}$ gm., in desiccator.	1	All insects dead....	Germination of fumigated seed superior to that of untreated seed.
Pineapples	<i>Pseudococcus</i> sp.....	do	$\frac{1}{2}$	do	Not planted.
Tussock moth (<i>Hemerocampa leucostigma</i>): 500 egg masses.	.....	Sodium cyanid, 2 gms.	$\frac{1}{2}$	Some larvæ hatched several days after exposure.	
250 egg masses.	.....	Sodium cyanid, 4 gms.	$\frac{1}{2}$	No hatching.....	

The results given in Table I indicate that the fumigation of seeds by the introduction of hydrocyanic acid into an air-tight chamber, from which the air has been practically exhausted, is effective, provided the exposure is not less than half an hour. An exposure of one-fourth hour is effective with the apparatus employed in these experiments if four or more grams of cyanid are used.

SUMMARY.

Fumigation by the method described in this bulletin was found to kill insects without injury to the seed and with a considerably shorter exposure than is necessary in the usual method of seed fumigation. Further experiments will be conducted with special reference to the use of carbon bisulphid, which is not considered in this paper.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 187



Contribution from the Bureau of Biological Survey, Henry W. Henshaw, Chief.

February 11, 1915.

PRELIMINARY CENSUS OF BIRDS OF THE UNITED STATES.

By WELLS W. COOKE, *Assistant Biologist*.

INTRODUCTION.

During the summer of 1914 the Biological Survey took initial steps toward a census of the birds of the United States for the purpose of ascertaining approximately the number and relative abundance of the different species. In view of the recognized value of birds to agriculture, such information can not fail to be of great value.

An added reason for this census was that the Congress has recently placed the Department of Agriculture in charge of migratory game and insectivorous birds, so that it is necessary that exact information be secured in regard to their present numbers as a basis for determining the adequacy of the present laws for their protection and whether the several species are increasing or diminishing.

The census will need to be repeated for several years and on a much larger scale before a satisfactory basis can be obtained for safe generalizations. It is hoped that all who can aid in the work will notify the Biological Survey in order that later necessary instructions and report blanks may be furnished. It will be understood that the bureau has no funds to pay for this work, and it must therefore depend upon volunteer observers. Bird observers in the West and the South are particularly requested to cooperate, as these sections have not been sufficiently covered in past observations. The circular of instructions for 1915 will be sent out early enough in the spring to allow ample time for making well-considered plans.

NOTE. This bulletin is a preliminary report on the number and relative abundance of wild birds. It is for the information of those interested in the protection and increase of birds.

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PREVIOUS BIRD CENSUSES.

The first publication of the results of a bird census on a large scale in the United States was in 1901, at Berwyn, Pa., where F. L. Burns reported 588 pairs of native birds breeding on 640 acres.¹ This is in very close agreement with the 583 pairs found to be the average for the present census under comparable conditions. There was no such agreement, however, in regard to the English sparrow, Mr. Burns finding 106 pairs to the square mile as compared with about 60 pairs as the average for the 1914 census.

In the summer of 1907 the University of Illinois conducted a series of statistical bird studies,² and during the month of June found 600 native birds per square mile as the average for southern Illinois, or less than half the number found to be the average in the national census. The method of conducting the Illinois census, however, was so radically different from that used by the Biological Survey that the two sets of figures are scarcely comparable. The Illinois census finds for the whole State 114 English sparrows to the square mile as compared with about 120 sparrows per square mile for the national census; but here, again, the differences are really greater than the above figures would indicate, for in the Illinois census a large number of the English sparrows counted were young birds.

The differences between these three censuses are most noticeable in the case of the English sparrow. For every 100 native birds enumerated in the bureau's census of typical farms of northeastern United States, seven English sparrows were found. The Berwyn census and the Illinois census showed 18 English sparrows per 100 native birds, but, as already stated, many of these in the latter census were young birds.

PLANS FOR THE 1914 CENSUS.

The first season's work must necessarily be regarded as largely preliminary, and the present publication, which may be considered in the nature of a report of progress, is issued for the double purpose of giving information as to the actual accomplishment in the preliminary survey and of increasing public interest in the matter so that next season the work may be greatly extended.

A bird census of a tract of land near Washington, D. C., had been taken for several years and the experience thus gained was used as a basis for the following circular of instructions:

¹ Burns, F. L. A Sectional Bird Census Taken at Berwyn, Chester County, Pa., During the Seasons of 1899, 1900, and 1901. *Wilson Bulletin*, No. 37, 1901, pp. 84-103.

² Forbes, S. A. The Mid-summer Bird Life of Illinois: A Statistical Study. *American Naturalist*, XLII, 1908, pp. 505-519.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF BIOLOGICAL SURVEY,
Washington, D. C., April 25, 1914.

DEAR SIR: The passage of the Federal law placing migratory game and insectivorous birds in charge of the Department of Agriculture makes it desirable to obtain more detailed and definite information concerning the distribution of bird life in the United States, and for this data we must look mainly to voluntary observers. This bureau desires to obtain a series of bird censuses, beginning with this summer (1914), taken during the breeding season, with a view to ascertaining how many pairs of each species of birds breed within definite areas. Such censuses will serve as a basis for determining later whether the present State and Federal laws are effective and whether game and insectivorous species are increasing or diminishing in numbers. In this undertaking you can materially aid by taking a census of the birds breeding this summer on some area or areas selected to fairly represent the average character of the country in your immediate neighborhood. The ideal tract of land would be one that exactly represents the average conditions of the neighborhood in the proportions of woodland, plowed land, meadow, etc., contained in it. As this idea is practically unattainable, an area should be selected representing fairly average farm conditions, but without woodland. It should not be less than 40 acres—a quarter of a mile square—nor more than 80 acres, and should include the farm buildings, with the usual shade trees, orchards, etc., as well as fields of plowed land and of pasture or meadow.

The area should be selected not only with reference to the present summer's work, but should, if possible, be chosen so that the physical conditions will not be much changed for several years; if succeeding annual censuses show changes in the bird population, it will be known that they are not due to changed environment.

What is wanted is a census of the pairs of birds actually nesting within the selected area. Birds that visit the area for feeding purposes should not be counted, no matter how close their nests are to the boundary lines.

It is practically impossible to take this census on the scale of 40 to 80 acres in a single day. A plan which has been used with advantage for several years is to begin at daylight some morning the last of May or the first week in June and zigzag back and forth across the area, counting the male birds. Early in the morning at that season every male bird should be in full song and easily counted. After the migration and the birds are settled in their summer quarters each male can safely be taken to represent a breeding pair.

The census of one day should be checked and revised by several days of further work, in order to insure that each bird seen is actually nesting within the area and make certain that no species has been overlooked.

The height of the breeding season should be chosen for this work. In the latitude of Washington—latitude 39°—May 30 is about the proper date for the original census. In the latitude of Boston the work should not begin for a week later, while south of Washington an earlier date should be selected.

The final results of the census should be sent to this bureau about June 30 and should be accompanied by a statement of the exact boundaries of the selected area, defined so explicitly that it will be possible 25 years hence to have the census repeated. The name of the present owner of the land should be given, together with a careful description of its character, including a statement whether the area is dry upland or moist bottom land, the number of acres in each of the principal crops, or in permanent meadow, pasture, orchard, swamp, roads, etc., the kind of fencing used, and whether there is much or little brush along any fences, roads, or streams, or in the permanent pasture.

If there is an isolated piece of woodland conveniently near and comprising 10 to 20 acres we should like to have a separate census made of the birds nesting therein.

In which case the report, in addition to the size and exact boundaries of the wooded tract, should state the principal kinds of trees and whether there is much or little undergrowth.

Still a third census desired is that of some definite area—as 40 acres, for instance—forming part of a much larger tract of timber, either deciduous or evergreen. While the number of birds on such an area would be far less than on an equal area of mixed farm land, their correct enumeration will require considerably more care and time.

The above are three kinds of bird censuses considered desirable, and it is hoped that you will volunteer to take one or more of them this season. In this connection we shall be very glad to have a statement from you concerning any changes you may have noted in the bird life of your locality, especially if your observations extend over a considerable number of years.

Should you desire further information in regard to the matter, we shall be glad to furnish it at any time.

Yours, very truly,

H. W. HENSHAW,
Chief Biological Survey.

Since no funds were available for this work, the above circular was sent to some 250 of the voluntary migration observers of the bureau, and a call was issued through the general press for volunteer census takers. There was a generous response and nearly 200 reports resulted. Some of the censuses were not properly taken owing to a misunderstanding of instructions and a few were incomplete from lack of acquaintance with some of the less common birds. However, there remains a sufficient number of satisfactory enumerations to serve as a basis for a few interesting deductions and to indicate the points which need to be more fully covered in future work.

RESULTS IN THE NORTHEASTERN STATES.

The larger number of censuses in 1914 were taken in the northeastern quarter of the United States, as shown by the map (fig. 1). Although 44 States are represented, less than a dozen reports came from the South Atlantic and Gulf States, and the number is no larger from the States west of the Rocky Mountains; while the reports from the Plains States—North Dakota to Oklahoma—are too few to be used as representing average conditions in this region. These three divisions, the South, the West, and the Plains, are so diversified in climatic and agricultural conditions and vary so widely in their bird life that many more bird censuses must be available before generalizations can be made for the whole country and reliable conclusions drawn.

The present report of progress concerns itself, therefore, with the census of birds on farms in northeastern United States, by which is meant the part north of North Carolina and east of Kansas. As the principal object of the proposed bird census was to ascertain the kind and number of birds on the farms of the United States, and as several of the most complete censuses were made on land which was not being

farmed or on which the conditions were evidently far different from the average farm, these censuses have not been used in computing the following averages, which are based on the enumerations apparently representing average farm conditions.

The average farm in the Northeastern States, according to the 1910 census, contains 108 acres, while the average area in the selected censuses is 58 acres, i. e., the census area consisted on the average of the farm buildings and the ground surrounding them together with approximately one-half of the land of the farm, leaving an average of 50 acres of land farthest from the buildings not covered by the census. Thus two problems are presented: First, how do the 58 acres

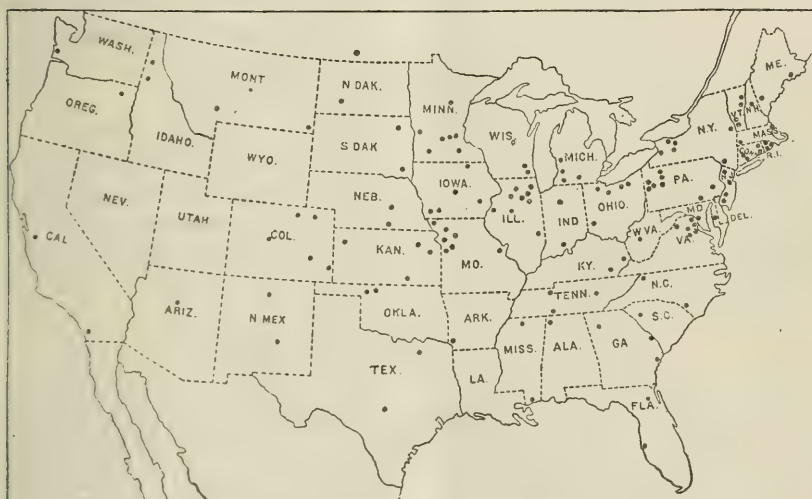


FIG. 1.—Places from which bird census reports were received in 1914.

covered by the census compare with the average farm; and second, how do the remaining 50 acres compare in bird population with the 58 acres chosen.

CENSUS-COVERED FARM LANDS.

That portion of the average farm covered by the census contained 30 per cent of plowed ground and 14 per cent of hay land, which, according to the 1910 census, is exactly the average percentage for the farms in this section of the United States. There is, however, a great difference in the relative size of the orchards; these farms contained 7.4 per cent of orchard, whereas the average for the northeastern quarter of the United States is only 1.2 per cent, or, in other words, the areas selected for the bird census contain six times as many acres of orchard as the average. Each area also contains the farm buildings with accompanying shade trees, ornamental shrubs, small fruits, and vegetable garden, forming the most favorable nesting sites on the

farm and affording the largest amount of food per acre. There is no doubt that the average 5 acres immediately surrounding farm buildings contain more birds' nests than any other 5 acres on a farm. As the farms selected contained orchards larger than the average, and as orchards are especially preferred by many kinds of birds for nesting sites, the areas selected evidently have a bird population denser than that of farm lands as a whole.

The letter of instructions asked specifically that censuses of woodland be made separately from the rest of the farm land, and many such censuses were received the average of which was 175 pairs to each 100 acres, while the farm land contained 119 pairs per 100 acres. It is evident, then, that comparatively small areas of woodland contiguous to cleared and cultivated land offer superior attractions as nesting sites and contain a correspondingly larger number of birds' nests than land which is wholly under cultivation.

The 58 acres on the average census-covered area of farm land is divided into 17 acres of plowed land, 8 acres of hay land, 4 acres of orchard, 3 acres of woodland, and, after deducting the land immediately surrounding buildings, 26 acres, about one-third of which is permanent meadow and two-thirds pasture land. These 58 acres support a bird population of 69 nesting pairs.

FARM LANDS NOT COVERED BY CENSUS.

The 50 acres of each farm not covered by the census consist on the average of 15 acres of plowed ground, 7 acres of hay land, 18 acres of woodland, and 10 acres divided between meadow and pasture. If the 18 acres of woodland contain on the average 31 pairs of birds, the other 32 acres would have to support a bird population of only 28 pairs to give these 50 acres the same bird population per acre as the part where the buildings are situated. It is not probable that the 32 acres would have quite 28 pairs, but they may easily have half that number, or a total of 114 pairs on 108 acres, practically one pair to the acre for the land in farms in the Northeastern States.

NONFARMED LANDS.

There remains the question of the bird population on the areas not included under the head of farm land. Again reverting to the returns of the census of 1910, in the great farming States of Iowa and Ohio this land represents less than 10 per cent of the whole area, almost a negligible quantity, while for New England it is just half the total area, and there is nearly as large a proportion in Wisconsin and Minnesota.

This nonfarmed land is largely forest, and unfortunately not a single bird census has been contributed from an area typical of forest conditions in the Northeastern States. The only census on a large

scale received of a true forest comes from near Coeur d'Alene, Idaho, and this shows 254 pairs of breeding birds on 768 acres, or one pair to 3 acres. The heavy timber of New England, of the mountains of Pennsylvania, of northern Michigan, and of northern Wisconsin would certainly contain a bird population no more numerous than that shown in Idaho, for it is well known that the heavy forest of the eastern mountains is a region of silence.

On the other hand, whatever land of the nonfarmed area is not covered by forest, whether it is marsh or rocky hillside, is fairly well supplied with birds and probably averages nearly as high in its avian population as the farm land. An estimate, therefore, of one pair of birds for each 2 acres on such nonfarmed land would be fairly accurate.

DEDUCTIONS FROM THE CENSUS.

NUMBER OF BIRDS TOO FEW.

That the present bird population is much less than it ought to be and much less than it would be if birds were given proper protection and encouragement is the most important deduction from this preliminary census. An approximate average of one pair of birds to each acre of farm land was found, but individual censuses show that it is possible, under strictly farm conditions, very largely to increase this number. Near Wellington, Va., a tract of 49 acres of a dairy farm, of rather less than the average of plowed land, supported a bird population of 137 pairs, or 3 pairs to the acre. The 15 acres surrounding a farmhouse at Port Byron, Ill., though more than half under cultivation, was found to contain 50 pairs of birds—a little more than 3 pairs to the acre. An 80-acre tract at La Grange, Ill., is described as "mostly dry upland; about 25 acres are covered with crops; very little pasture, one small orchard, two small swamps; no roads going through it, and in fact, this area is typical of the vicinity of La Grange;" yet this area showed 219 pairs of birds, or nearly three times as many as the average for the State. A similar area at Albany, Mo., "selected because it is ideal for the census, containing all the required conditions," was divided into 14 acres of plowed land, 27 acres of hay-fields, a brushy pasture, with a little heavy timber along the banks of a small stream, and the customary farmyard, orchard, garden, etc. The conditions for bird life were probably more favorable than the average, but not sufficiently different to account for the 298 pairs of birds nesting on the tract. A 40-acre farm at Rantoul, Kans., has 30 acres in clover and alfalfa, but the owner says that one strictly enforced rule on this ranch is protection for the birds, and that trees have been planted and groves arranged especially for nesting sites. The remaining 10 acres contain the buildings, 2 acres of orchard, 3 acres of groves, and a 2-acre artificial pond that never goes dry. The

consequence is that after 14 years of bird protection and encouragement, these 40 acres support 157 pairs of birds, or about 4 pairs to the acre.

POSSIBLE TO INCREASE NUMBER OF BIRDS.

It is evident from the foregoing statement that double the present bird population is easily obtainable, while a threefold increase is well within the possibilities.

The maximum census just cited of 4 pairs of birds to the acre does not by any means represent the largest number of birds that can be supported on a given area. In the summer of 1914, the 40 acres comprising the southern end of the National Zoological Park, at Washington, D. C., harbored 164 pairs of birds of 50 species—a notably large variety and a numerous population. Two blocks on the outskirts of Kenilworth, Ill., containing 15 acres, were reported to contain 84 pairs of birds. A section of five blocks at Chevy Chase, Md., covering 23 acres, showed a bird population of 148 pairs—nearly 7 pairs per acre. As this is the highest score reached in the census this tract will be treated more fully farther on in this bulletin.

But bird life can become even more abundant under proper conditions. On a 50-acre tract at Viresco, Va., where the birds have been strictly protected during the last seven years, exact censuses show a 50 per cent increase in the birds during the past four years. On the 3 acres containing the house, 15 pairs nested during 1914. On $1\frac{1}{2}$ acres about a city home at Cranston, R. I., 8 pairs of birds nested in 1914 where 12 pairs had nested in 1910, and the owner claims that cats are mainly responsible for the decrease. A field of 2 acres at Nevada, Iowa, on which was growing a variety of tree and bush fruits, as well as hardwoods, evergreens, and shrubbery, had been found and appreciated by the birds, as evidenced by 22 pairs nesting there. At Kenilworth, Ill., in the midst of the 15-acre tract previously referred to, stands a house whose owner "believes in befriending the wild birds—our friends and neighbors," and as a consequence, in 1914 his yard of half an acre had 9 pairs of birds

RECORD FOR DENSITY OF POPULATION.

The census at Chevy Chase, Md., showed the highest number of birds per acre of all the censuses so far reported to the Biological Survey. Here the owner of a half-acre yard, which was well supplied with trees and shrubbery, had put up nesting boxes and provided a bird bath, and was rewarded with a nesting population of 13 pairs of birds.

The census area consisted of about five blocks, selected from the most populous part of the village. These ranged from 3 to 6 acres in size and were all occupied by houses, from 5 to 10 houses to

the block. Each house was surrounded by a yard of from half an acre to $1\frac{1}{2}$ acres, the whole being abundantly supplied with large trees of oak and other hardwoods. Most of the houses in this section had been built within the last 10 years, but the area previous to that time was covered with heavy timber and as many as possible of the large trees had been preserved. In addition, an abundance of smaller trees and ornamental shrubs occupied a large proportion of the ground and there was almost a minimum of lawn for houses situated with such extensive grounds. The whole area is a residential section, containing no public buildings and occupied by a cultured class of people, many of whom have become interested in the subject of bird protection, with the result that numerous bird boxes have been put up and also a number of bird lunch counters for winter feeding. Practically all enemies of birds have been eliminated except the domestic cat, and its numbers here are below the average for such communities.

The result of all these conditions is that the village swarms with birds. When attempting to take a bird census in the early morning by counting the singing males, the chorus was so numerous at times that it was impossible to distinguish the individual songsters. The census showed 34 different species nesting on the 23 acres, with a total of 148 pairs of native breeding birds and 13 pairs of English sparrows. The most numerous species was the robin, 19 pairs; and following this came the catbird, 18 pairs; the purple grackle, 17; the house wren, 16; and red-eyed vireo, 10 pairs. Robins and catbirds were easily the most conspicuous species and their numbers alone were 50 per cent higher than the total normal bird population of this area. The presence of a very large number of cherry trees in each of the blocks—many of these trees being 30 to 40 feet high—as well as an abundance of bush fruits, may account for their specially large numbers. Almost all the cherries on these higher trees were left for the use of the birds.

It was noticeable that the blocks most thickly inhabited by people were also most fully occupied by breeding birds. This is a striking refutation of the widespread belief that human beings and birds are naturally antagonistic, and that as the population of the United States increases the number of the birds must necessarily decrease.

RELATIVE ABUNDANCE OF BIRDS.

One of the most abundant birds in the United States, possibly the most abundant bird, is the robin. It is also one of the most sociable, and in the northeastern part, where it is most abundant, it commonly nests close to farm buildings but almost never in extensive woods. Its numbers are exceedingly variable in the localities represented by

the bird censuses. All but three of the observers report its presence on the census-covered areas, while its numbers vary from one pair on a 49-acre tract in Virginia, and one pair on a 79-acre farm in western Pennsylvania, to 11 pairs on 80 acres in Vermont, 12 pairs on 100 acres in Maine, and 16 pairs on 70 acres in Connecticut. The densest robin population reported was 21 pairs on 40 acres at Meriden, Conn., and 19 pairs on 23 acres at Chevy Chase, Md., but in both cases the areas selected were village lots with no cultivated land and a maximum of attractive building sites in shade and fruit trees. The average of the censuses of robins on farms in northeastern United States is six pairs per farm on the 58 acres.

The next most common bird in the Northeastern States is the English sparrow. Ordinarily this bird is thought of as a city rather than as a country bird, for nowhere on farms can the flocks of hundreds be found which are a common sight during winter in the larger cities. However, nearly every farm has a few pairs and the number of farms is so great that the aggregate farm population is probably several times that in the cities. The census of farms in the Northeastern States averages five pairs of English sparrows to each farm.

No other bird is anywhere near as abundant as either the robin or the English sparrow, but several others are common enough to make their total numbers run well into the millions. For every 100 robins reported in the 1914 census there were 49 catbirds, 37 brown thrashers, 28 house wrens, 27 kingbirds, and 26 bluebirds. This last number is particularly gratifying because only a few years ago nearly the whole bluebird population of the Eastern States was destroyed by an unusually severe winter. Since then the birds have been gradually recovering from the catastrophe, and this season's census shows that there are now several million bluebirds in northeastern United States.

SUMMARY.

The census of birds of the United States was undertaken to ascertain the number and relative abundance of species as a basis for determining the adequacy of the protection now afforded them, in view of the law protecting migratory game and insectivorous birds.

While previous attempts were more local and not on the scale deemed necessary in the plans for the 1914 census, this census did not yield needful information from all parts of the country, the fullest reports coming from the Northeastern States.

The census will need to be repeated on a larger scale for several years and, for comparative purposes, should more fully cover the Southern and Western States, that the cause of increase or decrease in numbers may be determined, and that it may be known whether the changes are general or local.

The census covered 58 of the 108 acres of the average farm of the Northeastern States and revealed on this area a bird population of 69 nesting pairs, and on the remaining 50 acres it is estimated that there would be about one pair to the acre; in all, 114 nesting pairs to the 108 acres of farmed land. On the 46 acres of wild land existing for each 108 acres of farmed land it is safe to assume that there would be fewer birds than on the census-covered area.

The results of the census show that the numbers of birds are too few, and it is believed that with adequate protection and encouragement they can be materially increased. The record for density comes from Chevy Chase, Md., where 161 pairs of 34 species were found nesting on 23 acres.

This preliminary census shows that the most abundant bird on farms of the Northeastern States is the robin; that the next is the English sparrow; and that following these are the catbird, the brown thrasher, the house wren, the kingbird, and the bluebird in the order named.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 188



Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
March 15, 1915.

THE IMPORTANCE OF THICK SEEDING IN THE PRODUCTION OF MILO IN THE SAN ANTONIO REGION.¹

By STEPHEN H. HASTINGS, *Farm Superintendent.*

INTRODUCTION.

One of the most important needs in the agriculture of the San Antonio region of Texas is a dependable grain crop. For a number of years, corn was generally looked upon as the best grain crop for the region, but it has not proved to be dependable. The small grains are even less satisfactory. Because of the difficulties and failures of local grain production, it has been necessary to import a large proportion of the grain needed for local consumption.

Experiments have been conducted for several years at the San Antonio Experiment Farm to determine whether or not the grain sorghums could be depended upon to increase the local supply, as well as to give some stability to local production. The two principal grain crops of the region are oats and corn. The average yields per acre of oats and corn from the rotation experiments for the past six years and of early-planted grain sorghum (milo) for the past four years at the San Antonio Experiment Farm are shown in Table I.

TABLE I.—Average yields of oats, corn, and milo at the San Antonio Experiment Farm for the years 1909 to 1914, inclusive.

Year.	Yield per acre (bushels).			Year.	Yield per acre (bushels).		
	Oats.	Corn.	Milo.		Oats.	Corn.	Milo.
1909.....		9.8		1912.....	26.75	34.1	40.0
1910.....	10.70	8.0		1913.....	11.70	34.9	47.7
1911.....	8.50	10.6	32.0	1914.....	15.70	52.6	43.2

These figures indicate that, in the main, milo gives larger yields and is more dependable than either oats or corn. The average yield per acre of oats for the past four years, 1911 to 1914, was 15.7 bushels; of corn, 33.1 bushels; while the average yield of milo for the same period was 40 bushels. The last three years have been unusually favorable for corn production and the yields were considerably higher than may be expected, as the average yield for the past eight

¹ The experiments were conducted in cooperation with the Office of Cereal Investigations.

years, 1907 to 1914, inclusive, was only 24.4 bushels per acre. It is during years when the rainfall is low that milo shows a marked superiority over corn and oats, and it is probable that the figures given above do not do justice to milo. The results obtained at the experiment farm and by farmers who have given the crop a fair trial indicate that grain sorghum can be made a highly satisfactory grain crop in the San Antonio region if the proper varieties are grown and the necessary cultural methods are followed.

CAUSES OF UNSATISFACTORY YIELDS.

SORGHUM MIDGE AND THIN STANDS.

One of the chief difficulties encountered in the production of the grain sorghums in the vicinity of San Antonio has been the sorghum midge. It has been found, however, that by using reasonably quick-maturing varieties and planting them early a good crop can be produced before the midge appears in sufficient numbers to do serious damage. This matter has already been made the subject of a publication.¹

There are still numerous instances in which the yields have been low on certain farms. From the observations made on these farms, and also at the experiment farm, it appears that unsatisfactory yields are due, in many instances, to thin stands. Thin stands frequently result from thin seeding, which the farmers practice in the belief that with the low rainfall of the region thick seeding is not advisable. In this section thin stands permit excessive tillering or branching of the plants, and this results in delayed and nonuniform maturity. The thin stands and unsatisfactory maturity appear to be chiefly responsible for the low yields.

The tillers and branches of sorghum plants flower and mature later than the main stalks. The successful production of sorghum in the midge-infested regions depends upon the crop getting past the flowering stage before the midge appears. Earliness is of prime importance. As is shown in the results obtained in 1913, there may be years when there will be no great increase in yield from thick seeding. This was due to the fact that even the late-flowering heads were mature before the midge appeared. On the other hand, when, because of unfavorable weather conditions or for other reasons, planting is so delayed that the crop is in flower at about the time the midge appears, as was the case in 1914, uniform flowering is of prime importance if good yields are to be expected.

TILLERS AND BRANCHES.

All sorghums, when widely spaced in the row, produce an abundance of tillers and less frequently branches under the same conditions. Tillers are produced at or near the surface of the ground and appear when the plant has reached a height of only a few inches, but their

¹ Ball, C. R., and Hastings, S. H. Grain-sorghum production in the San Antonio region of Texas. U. S. Dept. of Agriculture, Bureau of Plant Industry Bulletin 237, 30 p., 1912.

appearance may be delayed until the plant is 18 inches or more in height. Tillers seldom appear after the stems of the plants have begun to develop, particularly if the plants are left close enough together to shield the lower parts from the light. The development of tillers is largely controlled by the distance apart of the plants and, to a lesser extent, by the soil and climatic conditions. Tillers have small heads and are later in maturing than the main stalk.

Branches indicate abnormal conditions and do not appear until the plant is well along in its growth. They occur only when the plants are spaced too far apart in the row or are supplied with an abundance of moisture. Every node above the ground except the terminal node may produce branches. The heads of the branches are still smaller and later in maturing than those of the tillers.

Branching is even more objectionable than tillering, as the ripening season is still further extended. Branches occur in abundance only when the plants are too far apart in the row and the temperature and moisture conditions are exceptionally favorable for a heavy vegetative growth during the latter part of the season.

EXTENT OF SORGHUM-MIDGE DAMAGE DURING 1913 AND 1914.

The season of 1913 was very favorable for the production of grain sorghum. Although the rainfall was about 2 inches below normal, the crop did not suffer severely from drought. The crop was well past the flowering stage before the sorghum midge appeared in sufficient numbers to do serious damage. Consequently, the insect had very little, if any, effect on the yield, even of the later plantings.

On the other hand, the season of 1914 was particularly unfavorable. The spring was unusually wet and cool, and, owing to these conditions at and after planting time, such poor stands were obtained that it was necessary to replant twice, which made the crop so late in coming to flower that there was a rather severe infestation of the midge in all the plats. This late flowering afforded an opportunity for determining the effect on the yield of suppressing the tillers and branches.

Suppressing the tillers, and thereby causing the plant as a whole to flower more uniformly, was of little value as far as the sorghum midge was concerned in 1913, but in 1914 the yields were extremely low on the plats where the plants tillered and branched freely. These low yields were due entirely to the fact that the heads of all the tillers and branches were sterile, owing to the ravages of the midge.

RESULTS OF THE EXPERIMENTS.

Experiments were conducted at the San Antonio Experiment Farm in 1913 and in 1914 to determine the effect of planting milo in rows at different distances apart and of thinning the plants to different distances within the row on the tillering, branching, uniformity, date of ripening, and yield of grain. These experiments are reported and discussed in this bulletin.

EFFECT OF PLANTING ROWS AT DIFFERENT DISTANCES APART.

The different widths between rows were tested in one-fifth acre plats, the rows being 264 feet long. The plants within the rows stood approximately 5 inches apart on all the plats, except where the stand was somewhat reduced by imperfect germination. The average number of plants per row, of mature heads per row and per plant, and the yield per acre are given in Table II. In this table, as well as in the following tables, the number of mature heads per plant and per row includes the main stalks and tillers, but not the branches, which when given are in another column.

TABLE II.—*Results of planting milo in rows at varying distances apart at the San Antonio Experiment Farm in 1913 and 1914.*

Distance between rows.	Number of plants per row.	Number of mature heads—		Average number of branches per plant.	Heads pendent.	Yields per acre.
		Per row.	Per plant.			
In 1913:					<i>Per cent.</i>	<i>Bushels.</i>
36 inches.....	350	879	2.5			42.9
40 inches.....	405	899	2.2			45.8
44 inches.....	339	959	2.8			45.3
48 inches.....	459	1,155	2.6			46.2
In 1914:						
36 inches.....	478	508	1.06	0.22	4	25.3
39 inches.....	439	472	1.07	.41	9	24.9
42 inches.....	498	532	1.08	.45	9	23.6
45 inches.....	529	552	1.04	.64	9	18.6
48 inches.....	504	542	1.08	.50	7	16.1

As Table II shows, no very marked effects were produced on the number of heads per plant by varying the width between the rows. The differences in yield were small. The results of the 1914 tests were similar to those conducted in 1913, except that an extra plat was included, as shown in the table.

There was practically no difference in the number of heads per plant when the rows were spaced at different distances, nor was there any consistent variation in the number of branches or pendent heads, although there is a tendency for the number of branches to increase as the distance between the rows increases, as shown by the 1914 results. The yields, however, uniformly increased as the distances between the rows decreased. This was to be expected, as the season was so favorable as to rainfall that even with the rows 3 feet apart the plants did not suffer from the want of rain. This table indicates that varying the distance between the rows does not appreciably affect the tillering or branching. The distance between rows will have to be governed by local conditions. Where the soil is rich and the rainfall abundant, the rows may be much closer together than they otherwise should be planted.

EFFECT OF DIFFERENT SPACINGS WITHIN THE ROW.

In six plats on which milo was planted in rows 4 feet apart in 1913 the plants were thinned to 18, 12, 8, 5, and 2 inches, respectively, within the row, one plat being left unthinned as a check. All the plats were one-tenth of an acre in size except the one on which the plants were thinned to 5 inches; this plat contained one-fifth of an acre. The results of this test are given in Table III. The "perfect stand" has been calculated as the number of plants which each row would have contained if the stand had been perfect. The actual stand stated was the average number of plants per row as estimated by counting the plants in one representative row in each plat. The number of heads was obtained by actual count, using the same rows that were used in determining the stand.

TABLE III.—Results of thinning milo plants to different distances within the rows, which were 4 feet apart and 264 feet long, at the San Antonio Experiment Farm in 1913 and 1914.

Perfect stand.	Actual spacing.	Stand (plants per row.)		Number of mature heads ¹ —		Average number of branches per plant. ²	Heads pendent. ²	Average height of plants.	Yield per acre.
		Per-fect.	Actual.	Per row.	Per plant.				
In 1913:	Inches.						Per ct.		Bushels.
18 inches apart.....	20.2	176	157	814	5.2	-----	-----	-----	42.5
12 inches apart.....	13.3	264	237	1,034	4.3	-----	-----	-----	42.1
8 inches apart.....	10.5	398	293	1,066	3.6	-----	-----	-----	43.8
5 inches apart.....	7.2	634	439	1,155	2.6	-----	-----	-----	46.2
2 inches apart.....	3.8	1,584	833	1,209	1.5	-----	-----	-----	46.4
Not thinned.....	3.5	-----	895	1,169	1.3	-----	-----	-----	46.4
In 1914:									
24 inches apart.....	24.5	132	129	393	3.04	3.44	29	4.8	1.2
18 inches apart.....	17.7	176	179	445	2.48	3.31	45	5.1	3.6
12 inches apart.....	12.7	264	254	375	1.48	2.64	32	5.5	6.6
8 inches apart.....	9.8	398	324	398	1.23	2.02	31	5.7	11.8
5 inches apart.....	6.3	634	504	541	1.07	.51	7	5.9	16.1
2 inches apart.....	3.5	1,584	902	936	1.04	.41	5	6.8	18.2
Not thinned.....	2.3	-----	1,364	1,415	1.04	.31	.6	7.3	21.8

¹ Includes tillers and main stalks.

² Based on the counts from one row only. All other results are the average of four rows.

The most important fact shown in Table III is that the number of heads per plant decreased consistently as the spacing within the row decreased. The average number of heads per plant in the 18-inch spacing was 5.2, while in the 2-inch spacing it was only 1.5, a decrease of 3.7 heads per plant. The yield, however, increased slightly as the plants were crowded within the row; that is, the thicker stands produced the higher yields.

The results of the tests made in 1914 are essentially a duplicate of those in 1913, an extra plat being added in which the plants were thinned to 24 inches in the row. All the plats used in 1914 were one-twentieth of an acre in extent, except the one thinned to 5 inches between plants, which was one-tenth of an acre. Additional columns show the average number of branches, the percentage of pendent heads, and the average height of the plants.

In general, the results of the tests made in 1914 agree with those obtained the previous year. For instance, in the 5-inch planting the tillers per plant in 1913 averaged 2.6, whereas in 1914 the average

was only 1.07, or less than in the unthinned plat in 1913. This was undoubtedly due to the seasonal conditions. The weather during April and May, 1914, was unusually wet and cloudy, during April especially so, while in 1913 the conditions were more nearly normal. Temperature

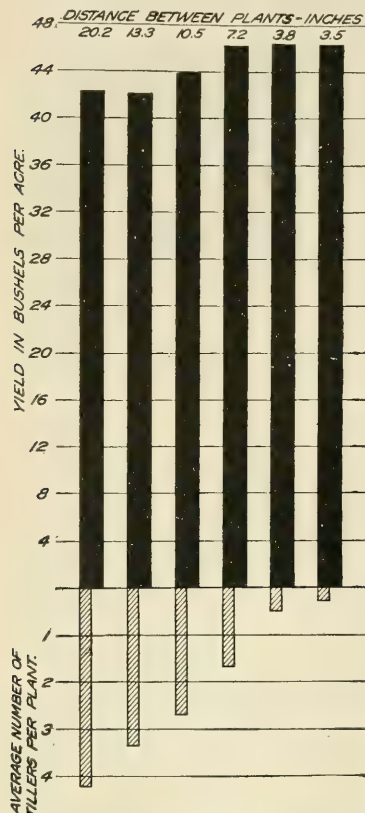


FIG. 1.—Diagram showing graphically the grain yields of milo and the tillers produced in the 1913 experiments. The solid columns indicate the yield in bushels, and the shaded columns represent the tillers.

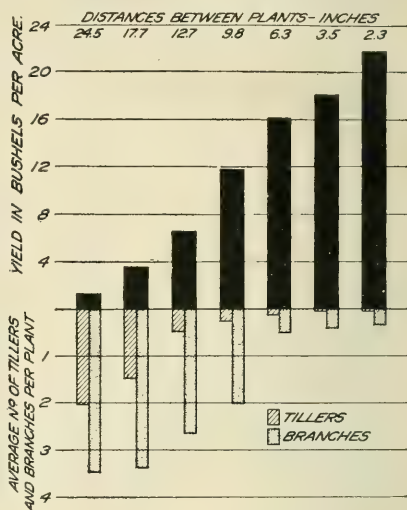


FIG. 2.—Diagram showing graphically the grain yields of milo and the tillers and branches produced in the 1914 experiments. The solid columns denote the yield in bushels, while the tillers are represented by diagonally shaded columns and the branches by dotted columns.

and sunlight, it appears, have a very marked effect on the number of tillers that are produced.

Another point brought out in the test of 1914, which was not noticeable the preceding year, was the branching of the plants, which took place after the warm weather set in. Counts were made of all the different plats at the time of ripening, and the number of branches averaged as high as 3.44 where the plants were spaced 24 inches apart. From this the number of branches decreased uniformly until there were only 0.31 per plant in the unthinned rows. It is probable that, as tillering did not take place until the plants were well along in growth and as there was an abundance of moisture in the soil, the plants spaced to a greater distance than 5 inches offset this wide spacing by sending out branches.

That the wider spacing in the rows increased the number of pendent heads is also brought out. The percentage of pendent heads increased from 0.6 per cent in the plat not thinned to 49 per cent in the plat where the plants were spaced to 24 inches apart.

It is evident that the yields from the plats in which the plants were spaced 12, 18, and 24 inches apart in the 1914 experiments were much lower than would be expected if the midge damage was uniform in the heads of the main stalks. Observations made at the time the heads were maturing showed that the damage by this insect in the three plats mentioned was much more severe than on the plats where the plants were spaced less than 12 inches apart in the row. It should be understood that this does not refer to the tillers or branches, for in no case, even on the plats where the plants were closely spaced in the row, did over 5 per cent of the seed set. The four rows of the plat where the plants were spaced 12 inches apart were located beside the four rows of the plat thinned to 2 inches apart, so that they were as nearly as possible on an equal footing, and there was no apparent cause for a greater midge infestation in one than in the other. The date of flowering of the main stalks was practically the same in both cases.

The effect of varied spacing on the yield and the production of tillers and branches is shown graphically in figures 1 and 2.

EFFECT OF ROW WIDTH AND SPACING ON TILLERING AND HEAD PRODUCTION.

On May 15, 1913, counts were made of the number of stalks per row and per plant on the plats already discussed. These counts were made when the plants were about 18 inches high. At harvest time the number of heads per plant on the same plants counted May 15 was determined. The results of these counts are given in Table IV.

TABLE IV.—*Stalks and heads per row and per plant on May 15 and at harvest time on nine plats of milo planted at different widths and spaced differently at the San Antonio Experiment Farm in 1913.*

Distance between rows.	Spacing.	Number per row.			Number per plant.	
		Plants.	Stalks, May 15.	Heads at harvest time.	Stalks, May 15.	Heads at harvest time.
	<i>Inches.</i>					
	(1)					
48 inches.....		895	2,601	1,169	2.9	1.3
48 inches.....	2	833	2,357	1,209	2.8	1.5
48 inches.....	5	439	2,198	1,155	5.0	2.6
48 inches.....	8	293	1,611	1,066	5.5	3.6
48 inches.....	12	237	1,504	1,034	6.3	4.3
48 inches.....	18	157	1,050	814	6.7	5.2
44 inches.....	5	339	1,950	959	5.7	2.8
40 inches.....	5	405	1,573	890	3.9	2.2
36 inches.....	5	350	1,753	879	5.0	2.5

¹ Not thinned.

Table IV shows that there was a marked decrease in the number of stalks per plant where the plants were crowded. From the yields obtained on these plats, particularly those shown in Table II, it appears that this reduction of tillering is advantageous from the standpoint of crop returns. As shown in Table IV, a large number of the stalks found on May 15 failed to mature heads. The production of nonbearing stalks or tillers uses soil moisture without any compensatory results. This being true, it seems desirable to reduce



FIG. 3.—Close-spaced milo plants, showing almost total freedom from tillers and the resulting high uniformity. (Photographed June 4, 1913.)

the number of stalks per plant, and it appears that this can be readily done by crowding the plants within the row, as is shown in figures 3, 4, 5, and 6.

EFFECT OF SPACING ON MATURITY.

One of the most important requirements for the successful production of grain sorghum in the San Antonio region is early and uniform maturity. This is necessary, in order that the crop may escape the ravages of the sorghum midge.

In the experiments conducted in 1913 a part of a row containing 50 plants was laid off on each of the six plats where the rows were 4 feet apart and where the spacing distances were varied. These plants were tagged and the date of maturity of each head was noted. Observations were made every two or three days during the ripen-



FIG. 4.—Milo plants thinned to 2 inches apart, showing the erect heads and the plants free from tillers and branches. Very little midge damage was done to the rows where the tillers and branches were suppressed by close spacing. (Photographed July 15, 1914.)

ing season. The results of these observations are given in Table V. The number of heads per plant of the 50 plants observed in each plat in this distance, as shown in the third column, is slightly different

in some cases from the estimate made to represent the entire plat, as shown in Table III, but the general relationship between the spacing of the plants and the number of heads per plant remains unchanged.



FIG. 5.—Wide-spaced milo plants, showing excessive tillering and lack of uniformity in heading and ripening. The seed is set on the main stalk, while on some of the tillers the heads are just beginning to flower and on others the heads are just emerging from the boot. (Photographed June 4, 1913.)

TABLE V.—Heads of milo matured on different dates in six plats, where the plants were spaced differently, the percentages being based on actual counts of 50 plants in each plat, at the San Antonio Experiment Farm in 1913.

Spacing.	Number of heads—		Percentages of mature heads.							
	On 50 plants.	Per plant.	June.					July.		
			21	24	26	28	30	2	5	8
Plats considered separately:										
Not thinned.....	63	1.2	62	75	87	88	89	95	100	.....
2 inches apart.....	78	1.5	60	79	91	91	92	95	98	100
5 inches apart.....	177	3.5	11	31	46	60	65	78	92	100
8 inches apart.....	174	3.5	14	34	46	54	65	82	94	100
12 inches apart.....	234	4.6	19	43	59	68	82	95	99	100
18 inches apart.....	231	4.6	13	43	53	67	83	97	99	100
Plats averaged in pairs:										
Not thinned and 2 inches apart.....	70	1.3	61	77	89	89	90	95	99	100
5 and 8 inches apart.....	175	3.5	12	32	46	57	65	80	93	100
12 and 18 inches apart.....	231	4.6	16	43	56	67	82	96	99	100

As shown in Table V, about 60 per cent of the heads on the close-spaced plants (unthinned and 2-inch spacing) ripened before June 21, and five days later practically 90 per cent of the heads on these plants were ripe. The ripening period, therefore, was approximately one week. On the other hand, only 11 to 19 per cent of the heads on the wider spaced plants (the spacings varying from 5 to 18 inches) ripened



FIG. 6.—Milo plants, spaced 24 inches apart, showing that when thus widely spaced practically all of the plants had one or more tillers and all branched freely. (Photographed July 15, 1914.)

before June 21, and on June 26, when about 90 per cent of the heads on the close-spaced plants were ripe, only about 53 per cent of the heads on the wider spaced plants had ripened. The ripening period of the heads on the wider spaced plants was about two weeks, or twice as long as that of the heads on the close-spaced plants. The earlier and shorter ripening period is a distinct advantage, particularly in allowing the crop to escape midge injury. It is evident, therefore, that in this connection, as well as in regard to crop yield, the thicker stands produced the best results.

A special point in connection with the maturing period of the differently spaced plants is that the plants in the six spacings fall into three distinct classes, based on time of maturity. In order to show this clearly, the lower part of Table V was compiled from the data in the upper part of the same table. The unthinned plants and those spaced to 2 inches are considered together as one class, those spaced to 5 inches and those spaced to 8 inches are considered as a second class, and the plants spaced to 12 and 18 inches are considered as a third class. The figures given are the averages of two spacings in each instance.

As already pointed out, the heads on the close-spaced plants ripened earlier than those on the plants spaced to 5 or more inches, but the table shows that the earliness was not proportionate to the closeness of spacing throughout the six plats. The unthinned plants and those spaced to 2 inches matured their seed at practically the same time; the widest spaced plants, 12 and 18 inches, came next in time of maturity; and the plants in the intermediate spacings, 5 and 8 inches, ripened last. This was probably due to the relative favorableness to tillering and to head production by the tillers resulting from the different spacings. The close-spaced plants produced very few tillers and the heads on the main stalks grew up and ripened promptly and uniformly; the widest spaced plants had the best conditions for tillering and the heads on the tillers had a fairly good opportunity to develop; but the plants spaced to intermediate distances, while producing a relatively large number of tillers, were sufficiently crowded to make it difficult for the heads on the tillers to reach maturity.

While the widest spaced plants matured earlier than those spaced to intermediate distances, and in this respect produced more favorable results, it is likely that the stumps left after harvest would be larger on the widest spaced plants, and this would be a serious objection, as is pointed out later. Considering the entire series, the results obtained with the closest spacing show that thicker seeding is much to be preferred.

In the results obtained in the 1914 test, as is indicated in Table III, giving the yields, none of the tillers or branches produced seed. There was a rather severe infestation of the field with midges at the time the first heads (main stalks) were in flower, so that when the later heads (branches and tillers) flowered, the field was so badly infested that the heads were practically sterile.

As is shown in Table III, close spacing resulted in only a slight increase in the number of stalks per row over the number produced by wide spacing, up to 12 inches. Table VI, a comparison of the 1913 results of the 12-inch spacing and of the rows in which the plants were not thinned, shows this condition.

TABLE VI.—*Plants and heads of milo in rows differently spaced at the San Antonio Experiment Farm in 1913.*

Spacing.	Number per row.	
	Plants.	Heads.
Not thinned.....	895	1,169
12 inches apart.....	237	1,034
Difference.....	658	135

Table VI shows that while the number of plants per row in the unthinned rows exceeded by 658 that of the rows in which the plants were 12 inches apart, the number of heads per row differed by only 135. This difference in the number of heads per row is seen to be very slight when it is considered that the rows were 264 feet long. Consequently, when seeds are so placed as to have the plants 6, 8, or 12 inches apart in the row, with the idea that less moisture will

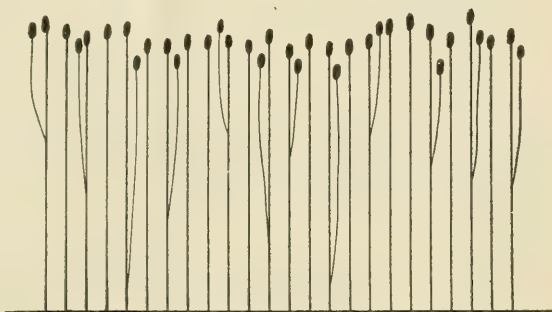


FIG. 7.—Diagram showing the appearance of milo plants when spaced closely together.

be required to mature the crop, the grower may actually obtain as many heads per row as would result from thicker seeding, and he may find that the moisture requirement has not been reduced at all. Furthermore, the thin seeding, by promoting tillering, would delay maturity.

FIG. 8.—Diagram showing the appearance of milo plants when spaced 12 inches apart: *a* and *g*, Tillers; *d* and *j*, main stalks; *b*, *c*, *e*, *f*, *h*, and *i*, branches.

thinned. Figure 8 shows the spacing of the plants and the tillers and branches in the plat thinned to 12 inches. Figure 9 is made up from figure 8; that is, it shows how the row would appear if the tillers and branches were removed and placed between the main stalks, and it should be compared with figure 7. It will be seen that in reality there are nearly as many stalks per row in the 12-inch plants

Figures 7, 8, and 9 illustrate this. These diagrams were made up from Table III. Figure 7 shows the spacing of the plants in the plat not

ing as in the plat not thinned. The actual counts show that the plants in the unthinned plat average 2.3 inches apart. Assuming that the tillers and branches were plants in the plat thinned to 12 inches, the plants would then average 3 inches apart, or only 0.7 of an inch farther apart than the plants in the unthinned plat.

The rainfall at the San Antonio Experiment Farm from the planting time to the ripening period of the milo in the 1913 experiments



FIG. 9.—Diagram made up from figure 8, showing the branches and tillers removed and placed between the milo plants: *a*' and *g*', Tillers; *d* and *j*, main stalks; *b*', *c*', *e*', *f*', *h*', and *i*', branches.

was about 2 inches below normal. This condition was particularly favorable for comparing the results obtained from different plant spacings. These results, together with numerous observations made in previous years, both at the experiment

farm and on other farms in the region, indicate that relatively close spacing within the row is preferable to wide spacing, even when the rainfall of the growing season is relatively low. The results of the experiments indicate that the plants should be approximately 3 or 4 inches apart within the row.

VARIATIONS IN TILLERING.

There is a marked difference in the amount of tillering in the two years that the test has been carried on. (See figs. 1 and 2.) For the purpose of comparison, Table VII has been included.

TABLE VII.—*Tillering of milo plants differently spaced in rows 264 feet long at the San Antonio Experiment Farm in 1913 and 1914.*

Perfect stand.	Actual spacing (inches).		Stand (plants per row).		Number per plant.					
					Mature heads.		Branches.		Branches and tillers.	
	1913	1914	1913	1914	1913	1914	1913	1914	1913	1914
24 inches apart.....		24.5		129		3.04		3.44		5.48
18 inches apart.....	20.2	17.7	157	179	5.2	2.48		3.31	4.2	4.79
12 inches apart.....	13.3	12.7	237	254	4.3	1.48		2.64	3.3	3.12
8 inches apart.....	10.5	9.8	293	324	3.6	1.23		2.02	2.6	2.25
5 inches apart.....	7.2	6.3	439	504	2.6	1.07		.51	1.6	.58
2 inches apart.....	3.8	3.5	833	902	1.5	1.04		.41	.5	.45
Not thinned.....	3.5	2.3	895	1,364	1.3	1.04		.31	.3	.35

The most striking difference in the 1913 and 1914 results is in the reduction of the number of tillers in 1914 and the appearance of branches, which did not occur the previous year. However, in the

wider spacings the total number of branches and tillers is about equal to the total number of tillers alone in 1913. In the close spacing there was a decidedly smaller number of tillers and branches combined than in 1913. This variation is unquestionably due to the rather unusual weather conditions during the months of April and May, 1914. The weather conditions for the first six months of each year and the averages, as given by the United States Weather Bureau for a number of years, are shown in Table VIII.

TABLE VIII.—*Aspect of the sky, temperature, and rainfall at San Antonio, Tex., for the first six months of the years 1913 and 1914, showing also averages for stated years.*

Month.	Aspect of sky.									Temperature (° F.).									Rainfall (inches).					
	Days clear.			Days partly cloudy.			Days cloudy.			Mean maxi- mum.			Mean mini- mum.			Mean.								
	Av. ¹	1913	1914	Av. ¹	1913	1914	Av. ¹	1913	1914	Av. ¹	1913	1914	Av. ¹	1913	1914	Av. ¹	1913	1914	Av. ²	1913	1914			
January.....	10.6	9	24	9.5	9	4	10.8	13	3	63.1	62.1	68.4	42.6	42.7	44.4	52.8	52.4	56.4	1.32	0.96	0.09			
February.....	9.6	11	10	8.3	11	8	10.3	6	10	65.4	62.1	63.5	44.4	42.0	42.8	54.8	52.0	53.2	1.71	1.91	1.38			
March.....	9.6	18	17	10.5	9	6	10.9	4	8	73.7	70.8	69.9	52.1	47.9	47.8	62.9	59.4	58.8	1.75	1.36	.83			
April.....	8.2	16	13	11.6	9	5	10.5	5	12	79.8	79.1	77.8	58.8	54.7	55.8	66.9	66.8	66.8	2.69	1.32	5.26			
May.....	8.0	20	4	11.3	9	16	8.0	2	11	85.1	87.1	82.3	65.3	64.1	66.4	75.1	75.6	74.4	3.04	2.88	5.59			
June.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	91.2	88.3	91.2	70.8	70.2	72.8	80.9	79.2	82.0	2.62	2.90	.01			
Total.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.13	11.27	13.16			

¹ Average for the years 1877 to 1913.

² Average for the years 1871 to 1913.

While Table VIII shows no great variation in the temperature during the growing months, there was an unusual difference in the aspect of the sky for the months of April and May, the months when most of the tillers and branches were being formed. For example, there were three more clear days in April and sixteen more in May in 1913 than in 1914. There were over twice as many cloudy days in April and over five times as many in May in 1914 as in the same months of the previous year. It is certain that light has a very marked effect on the development of tillers, and the only reasonable explanation to be offered in the variation in tillering during the two years seems to be a corresponding variation in light, as the soil conditions were very similar. There was a much greater rainfall in 1914 than in 1913 during the months of April and May, as is shown, but this, if it would influence the results in any way, would be likely to make conditions more favorable for tillering. It would seem, on the whole, that an intermediate between the two seasons is much nearer the mean than either of the two seasons during which the experiments have been conducted. It is reasonable to conclude that in most seasons tillering might be somewhat less than in 1913, but much greater than in 1914, especially in the closer spaced plantings. Branching before the plants mature is abnormal and rarely occurs to any appreciable extent in grain sorghums at San Antonio.

THICK SEEDING AND THE SIZE OF PLANT STUMPS.

Another advantage derived from seeding thicker than is customary is the reduced size of the plant stumps. One of the objections advanced against the growing of grain-sorghum crops, particularly in the black lands of Texas, is the difficulty of preparing the land for the succeeding crop. Where the plants grow very large the increased size of the rooting system necessary to support a plant with several stalks often causes soil to adhere to the roots, forming large masses of mixed roots and soil. When the land is plowed, many of these large clods, which are very difficult to turn under, are left on the surface, greatly increasing the difficulty of properly preparing the seed bed. Thicker seeding, by reducing the size of individual plants, markedly lessens this difficulty.

THICK SEEDING AND CROP STANDS.

It is obvious that the best results can not be secured with milo where the stand is irregular and spotted. Where relatively thin seeding is practiced the chances of getting a good, uniform stand are reduced. There are numerous conditions that operate to prevent high germination of the seed and successful growth of the crop, and, within reasonable limits, thick seeding is desirable, as it increases the chances of securing a good stand in spite of adverse conditions of soil and climate. There is little danger of getting the milo plants too close together in the row so long as the rate does not greatly exceed 5 pounds of seed per acre, the rate used in these experiments, with rows 4 feet apart. As is shown in Table III, the highest yields were obtained from the unthinned rows and the 2-inch spacing. In 1913 both these plats yielded at the rate of 46.4 bushels per acre. In 1914 the two plats so spaced yielded at the rate of 21.8 and 18.2, bushels, respectively. It seems certain that to secure satisfactory stands it is desirable to plant at a rate at least as high as 5 pounds of seed per acre. This would make a rather thick seeding if every seed produced a plant, but this is seldom the case. The experiments carried on with milo at San Antonio have shown that if the planter plates are so arranged that only one seed is dropped where a plant is desired, such a poor stand will generally result that the yields will be very materially decreased. In the experiment described above, with a seeding rate of 5 pounds per acre, if every seed had produced a plant the plants would have averaged about 1.5 inches apart, or 2,112 plants to a 264-foot row. But, as is shown in Table III, there were only 895 mature plants per row in the plat that was not thinned.

THICK SEEDING AND MATURITY.

It has already been shown that the closer spaced plants matured earlier and more uniformly than those which were farther apart in the row. As shown in Table V, the difference in earliness of maturity

was approximately one week. This is of profound importance in escaping injury from the sorghum midge. It has been found at the San Antonio Experiment Farm that a few days' delay in the time of flowering may result in the almost complete destruction of the crop by this insect. This is strongly emphasized in the 1914 results. Thick seeding, then, by insuring that the plants will be close together within the row, is favorable in its effect upon the maturity of the crop.

THICK SEEDING AND CROP YIELD.

From what has been stated about the favorable effect of thick seeding upon the stand and maturity of the crop, it would be expected that the yield would be favorably affected also. This expectation was fully realized in the 1913 experiments and strongly emphasized again in the 1914 experiments, as indicated in Table III, which shows that the yield increased consistently as the spacing of the plants within the row decreased from 24 inches to 2 inches.

THICK SEEDING AND RAINFALL.

It has been supposed by many that the rate of seeding of grain crops should always be greatly decreased in regions of low rainfall. This supposition is probably not always well founded, because most grain crops tend to offset thin seeding by tillering. Early and uniform ripening is frequently of great importance in dry regions, because it assists the crop in evading midseason droughts and also, in many cases, in escaping insect injury. It seems that thin stands promote excessive tillering of milo, with resulting lateness and lack of uniformity in ripening. (See figs. 5 and 6.) It has also been shown in Table II that increasing the distance between rows has little, if any, effect on the production of tillers. It seems, therefore, that where the question of moisture is an acute one, the conditions should be met by increasing the distance between the rows rather than that between the plants within the row.

If the moisture supply could be controlled so that it would be uniform from year to year, there is a certain distance apart that the rows might be planted to get the maximum yield, which in no way has any connection with the distance apart of the plants within the row, even where the rainfall is limited. Large plants with several tillers may actually suffer more during a dry period than several plants each with only a single stalk occupying the same space, because where each stalk has its own rooting system it can use the moisture more effectively.

TIME OF THINNING.

For the purpose of determining the effect of thinning to 12 inches apart at various dates on the number of tillers and branches, a small area was devoted to this test. The rate of seeding used in this test

was the same as in the other experiments, so that the average distance between the plants before thinning was slightly over 2 inches. Owing to the smallness of the area the yields were not measured, and as there were only two rows in each plat in the center of the field it is probable that the behavior of the plants in this test was influenced to some extent by adjoining rows. Table IX gives the total number of plants considered and the average number of mature heads and branches per plant.

TABLE IX.—*Heads and branches of milo plants, showing the effect of thinning at various dates at the San Antonio Experiment Farm in 1914.*

Date thinned.	Number of plants.	Number per plant.	
		Mature heads.	Branches.
May 12.....	58	1.26	0.43
May 25.....	84	1.19	.23
June 2.....	73	1.13	1.00
June 9.....	70	1.03	1.30

While the difference between the first and last thinning is not great, there is a fairly consistent variation. There is a gradual decrease in the number of mature heads from the first to the last thinning date, but the reverse is the case with the number of branches, as they increase as the date of thinning is delayed. This is to be expected, for, as has been shown in previous tables, the 12-inch spacing between plants is so wide that they will send out either tillers or branches to offset it. Where thinning is delayed long enough to allow the plants to become of sufficient size to largely prevent tillering, as was the case with the June thinnings, branches will be produced if the conditions during the later part of the season are sufficiently favorable.

While, as already intimated, too much importance should not be given to the data in this table, the results are in accord with the previous experience of the writer and indicate that the time of thinning is not of great importance if it is done early enough to avoid injury to the adjoining plants. If the thinning is done when the plants are very small, there may be produced a considerable number of tillers, a very small percentage of which will not develop, owing to crowding later in the season. This is shown where counts were made early in the season and at ripening time (Table V, p. 10). In the field plantings on the experiment farm during the last two years it was found to be unnecessary to do much thinning. In 1913 the time consumed in thinning the field plantings was not greater than was necessary to thin corn, where the plants were thinned to 2 feet apart in the row. No thinning was necessary in 1914. In both years the rows were 4 feet apart and about 5 pounds of seed to the acre were planted.

ADVANTAGES OF THICK SEEDING.

In the foregoing discussion reference has been made to close spacing and wide spacing rather than to thick seeding and thin seeding. This terminology has been used because it conforms to the methods used in the experiments reported. For convenience in securing accurate counts and measurements, it was thought desirable to plant all the plats at the uniform rate of 5 pounds of seed to the acre, although it was necessary to replant twice in 1914, using a heavier rate. This is a relatively thick seeding if conditions are favorable. The plants were then thinned to varying distances within the rows to correspond approximately to the stands which would result from various rates of seeding. In actual practice the stand is regulated by varying the rate of seeding, as it is not generally considered practicable to thin the plants in a large field. The close spacing which seems to be desirable must be secured by relatively thick seeding.

The results obtained from the tests covering two years show clearly two things: (1) That even in favorable seasons when the midge is not a factor the yields are not decreased by thick seeding and (2) that in years when the midge appears at about flowering time the yields are very materially increased when the tillers and branches are suppressed by thick seeding.

From even the purely theoretical standpoint, where no other factors are involved, it would seem that if a tiller is given a root of its own it will do better than when several heads are dependent upon a single rooting system, which is indicated in the results obtained in 1913. In other words, when earliness is not a factor, the yields are not decreased when the tillers are suppressed. In fact, the weight of evidence indicates that the thicker seedings are better.

THICK SEEDING IN OTHER SECTIONS.

It is appreciated that the number of tillers produced depends, aside from the spacing of the plants in the row, upon the productivity of the soil and upon the climatic conditions. Where the conditions vary considerably from those at San Antonio it is realized that the results would doubtless vary greatly with similar experiments. This does not in any way affect the value of these results nor prohibit the application of the principle, but simply shows the necessity of conducting experiments to determine the proper spacing of the plants in the row and the distance between rows for the locality.

Aside from the data herein given, very little information is available relative to the effect of various spacings on the behavior of grain-sorghum crops. That other factors are involved besides the available moisture supply seems not to have been recognized. Fragmentary statements are found here and there in various publications which have intimated that where thin rates of seeding were made

the plants have stooled or tillered sufficiently to seemingly offset the thin stand. This tillering habit has been frequently referred to as desirable. It is yet to be proved that thin seeding, with its attendant heavy tillering, will anywhere give a heavier grain yield than a thicker seeding which largely prevents tillering. The chief advantage, if not the only one, derived from tillering seems to be that where, owing to unfavorable conditions at the time of planting, a poor stand is secured, tillering tends to offset this and the yield of grain is generally, although not always, increased. The logical conclusions, in the light of the experiments cited in this bulletin, indicate that the rate of seeding should be heavy enough to prevent tillering.

SUMMARY.

(1) Experiments conducted at the San Antonio Experiment Farm since 1909 and observations made on other farms in the vicinity show that grain sorghum can be made a very satisfactory grain crop for the region if the proper varieties are grown and the necessary cultural methods are followed.

(2) One of the chief reasons for unsatisfactory yields appears to be the poor stands which frequently result from thin seeding. Poor stands result in late and nonuniform maturity and low yields, particularly when delayed maturity subjects the crop to the depredations of the sorghum midge.

(3) Experiments with milo were conducted at the San Antonio Experiment Farm in 1913 and 1914 to determine the effect of planting in rows at different distances apart and of thinning the plants to different distances within the rows on the tillering and branching, the uniformity and date of ripening, and the yield.

(4) No marked differences resulted in the number of tillers or the number of heads per plant from varying the distance between rows.

(5) In the plats where the rows were uniformly 4 feet apart, but where the plants were thinned to different distances within the rows, the number of heads per plant decreased and the yield increased as the plants were crowded, the thicker stands producing the higher yields.

(6) Counts made of the number of tillers per plant on May 15 and of the number of mature heads per plant at harvest showed that a large number of tillers on the wide-spaced plants failed to produce heads.

(7) The close-spaced plants ripened their grain in 1913 about one week earlier than the wide-spaced plants. This early maturity is particularly important in that it permits the crop to escape the sorghum midge.

(8) Increasing the number of plants per row does not necessarily mean a proportionate increase in the total number of heads or stalks per row.

(9) The weather conditions influence very markedly the number of tillers and branches produced, although the total number of branches and tillers produced in 1914 about equaled the total number of tillers alone in 1913, when there were but few branches.

(10) In practice, the stand is controlled by varying the rate of seeding rather than by thinning the plants; thick stands are secured by thick seeding.

(11) Thicker seeding than is ordinarily practiced appears to be desirable, in that it results in smaller and more easily handled plant stumps, gives better stands, insures earlier and more uniform maturity, and produces better yields. A rate of 5 to 6 pounds per acre, where the rows are 4 feet apart, is recommended.

(12) It would appear that the close spacing of the plants can be practiced in sections of low rainfall. To offset this increase in the number of plants per row it is necessary only to increase the distance between the rows.

(13) The time the plants are thinned does not seem to be an important factor in suppressing tillers and branches. If the thinning is delayed sufficiently to reduce tillering, there seems to be a tendency for the plants to increase the number of branches.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 189

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.



April 12, 1915

STUDIES OF THE CODLING MOTH IN
THE CENTRAL APPALACHIAN
REGION

By

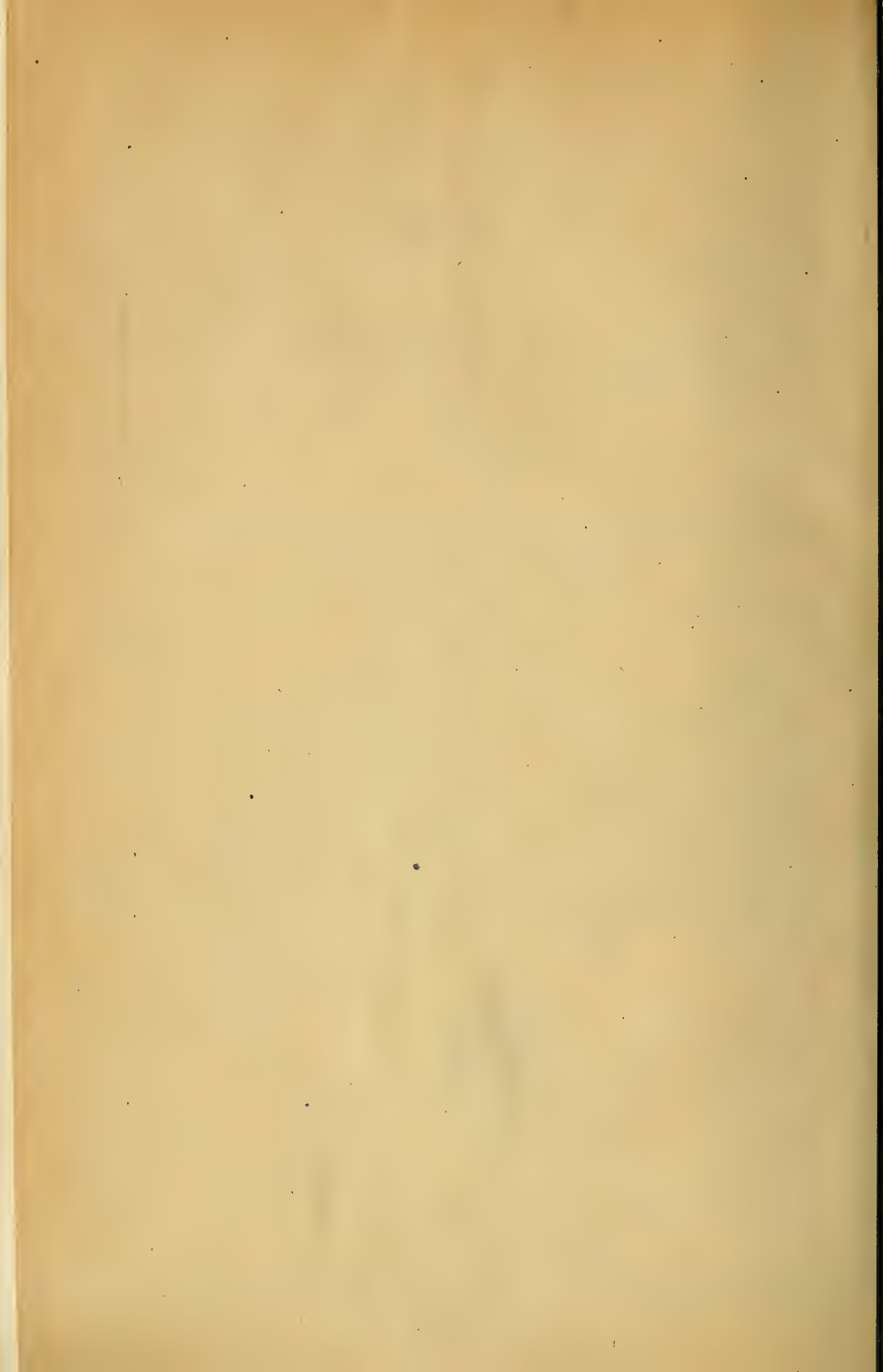
F. E. BROOKS and E. B. BLAKESLEE, Entomological Assistants
Deciduous Fruit Insect Investigations

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STUDIES OF THE CODLING MOTH IN THE CENTRAL APPALACHIAN REGION.

By F. E. BROOKS and E. B. BLAKESLEE,
Entomological Assistants, Deciduous Fruit Insect Investigations, Bureau of Entomology.

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INTRODUCTION.

In many localities throughout the central Appalachian region the recent rapid development of the apple-growing industry has made the control of the codling moth (*Carpocapsa pomonella* L.) a subject of special and increasing interest. The hilly or mountainous nature of the land has led to the location of orchards at elevations ranging from a few hundred feet to more than 4,000 feet above the level of the sea. The great diversity of temperature that occurs between the lower and the more elevated orchards has a marked effect on the time of transformation of the different stages of the codling moth, and consequently has direct bearing on the relative number and the destructiveness of second-brood larvæ.

In the spring of 1911 the Bureau of Entomology began a study of the codling moth in the region just mentioned, as a part of its inves-

tigations of this insect throughout the United States, giving particular attention to time of appearance of the different broods at various altitudes and latitudes. The work was conducted by or under the immediate direction of the authors of this paper and was continued for three consecutive years at several points located in Virginia, West Virginia, and Maryland.

The writers are greatly indebted to the large number of fruit growers in the various localities where the investigations were carried on for the free use of orchards in which to obtain banding records, for buildings to shelter rearing jars, and for other courtesies. During the progress of the work many essential suggestions were made by Prof. A. L. Quaintance, in charge of Deciduous Fruit Insect Investigations, under whose direction the studies were made.

LOCALITIES IN WHICH INVESTIGATIONS WERE MADE.

The studies described herein were conducted at Charlottesville, Fishersville, Greenwood, and Winchester, Va.; Keyser, French Creek, and Pickens, W. Va.; and Hagerstown, Smithsburg, and Hancock, Md. The senior author had charge of the investigations in West Virginia and the junior author had charge in Virginia and Maryland. At several of the points mentioned only partial or incomplete records were obtained. The similarity of conditions at Smithsburg and Hancock, Md., and Keyser, W. Va., to other localities where records were being kept, together with a shortage of the fruit crop and the difficulty of visiting so many places at sufficiently frequent intervals, led to the discontinuance of operations at these points after the first year.

NATURE AND EXTENT OF THE INVESTIGATIONS.

The work was conducted by selecting, for banding, from 10 to 15 unsprayed bearing apple trees of late ripening varieties in each locality. Wherever it was possible medium-sized trees with smooth bark were chosen. In some cases such trees could not be found and old trees with rough bark were used. The rough scales of bark were scraped from the trunks and from the bases of the larger branches of these old trees, but even then they were much less desirable for the purpose than the younger, smooth-barked trees.

In the spring, before the first-brood codling-moth larvæ had commenced to leave the fruit, burlap bands were tied around the trunks of the trees 2 or 3 feet above the ground, and in some cases additional bands of the same material were placed around the bases of the larger branches. The trees were all tagged and an individual account kept as to the number of larvæ going under the bands to "spin up." The bands were removed and examined at frequent intervals and the

larvæ taken from them were counted and placed in rearing jars. In 1911 the larvæ were collected and the rearing jars examined every 10 or 12 days, and in 1912 and 1913 the examinations were made every 3 or 4 days. During the course of the work more than 20,000 larvæ were collected and placed in the jars for rearing.

The jars containing the larvæ were supplied with small devices made of thin pieces of wood bound together, with openings between into which the larvæ entered to "spin up." It was found that strips cut from sheets of transparent celluloid could be used under the wood to advantage, as this permitted the wood covering to be removed for the purpose of examining the larvæ or pupæ without tearing or disarranging the cocoon. The jars were covered with cheesecloth and were placed under shelter, usually in open sheds, where they had out-of-door temperature. These sheds were always located near the orchard in which the larvæ had been collected. The jars were examined on the same dates as the bands, and the moths that had issued at each examination were counted and destroyed. Larvæ that wintered were preserved and records were made of the date they issued as moths the spring following. So far as possible the band records were checked and supplemented by observations on the condition of the insect in the orchard.

EXPLANATION OF THE USE OF TERMS.

The terminology of this paper is made to conform as nearly as possible with that of previous papers on the codling moth issued by the bureau. The term "generation" applies to the moth in all its stages from the egg to the adult, regardless of whether the life cycle is completed in one season or whether the insect winters during its development, in which case the life cycle would occupy parts of two seasons. The term "brood" is used to designate the insect in any of its four stages. Broods of eggs, larvæ, pupæ, and imagoes occur normally, with more or less seasonal regularity, in the orchards of any given locality, and the term "brood" usually refers to the individuals in the aggregate of any particular stage of a given generation.

In the Appalachian section a first brood and a partial, or practically full, second brood of larvæ occur annually. In some southern localities a small third brood is possible. Some of the larvæ of the first brood and practically all those of the second brood winter in the cocoon. These are all spoken of as "wintering larvæ." In the spring these wintering larvæ transform to "spring pupæ," which in turn develop into "spring moths." The spring-brood moths produce "first-brood eggs," from which hatch "first-brood larvæ." The individuals of this generation that complete their transformation during the first season are known in their successive stages as "first-brood

pupæ" and "first-brood moths." These moths in turn produce "second-brood eggs" and "second-brood larvæ." Where "second-brood pupæ" and "second-brood moths" occur they may produce "third-brood eggs" and "third-brood larvæ."

INVESTIGATIONS AT CHARLOTTESVILLE, VA.

DESCRIPTION OF LOCALITY.

Charlottesville is situated at the foot of the eastern slope of the Blue Ridge Mountains, at an elevation of 400 to 500 feet above sea level. In the immediate vicinity of the city there are several large and profitable bearing apple orchards, as well as a considerable acreage of young orchards planted within the last four or five years. Its own interests, therefore, as well as its proximity to the large orchards of the Blue Ridge section, make Charlottesville of considerable importance as a commercial apple-growing center. Investigations of the seasonal life history of the codling moth were carried on in this section in 1911, 1912, and 1913. Only the work of the last two years, however, was considered of sufficient value to be included in this report.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

A large proportion of the larvæ collected in the orchard in the fall of 1911 succumbed to cold or disease the following winter, and the rearing material available for moth emergence was consequently rather limited. On account of the small number of insects reared and some irregularity in the observations the records are not included in detail. Moths were first observed in the rearing cages at Charlottesville on May 7, and at Greenwood, where conditions are not far from those at Charlottesville, adults began appearing about May 8. Also the summer brood of moths emerged in the rearing cages at Charlottesville 45 days later (June 20), which is about the interval that must elapse between the two broods of adults in that latitude. Therefore we may safely assume that in 1912 the emergence of spring-brood moths began in the orchards at Charlottesville soon after May 1.

FIRST-BROOD MOTHS.

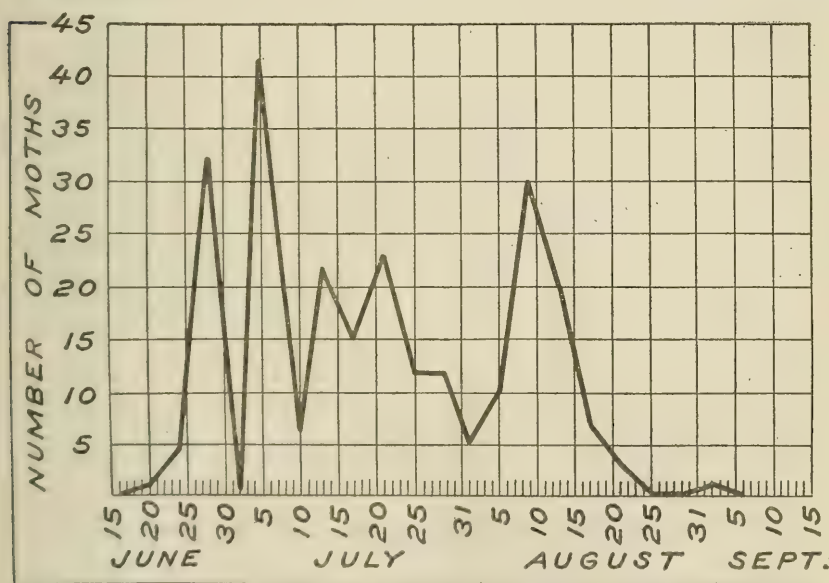
Table I gives the time of emergence of 247 moths that issued from band-collected material at Charlottesville in 1912. Beginning on June 20, emergence continued through the rest of June, the whole of July, and about half of August. One moth emerged as late as September 2.

TABLE I.—Emergence of first-brood moths of the codling moth at Charlottesville, Va., in 1912. (See fig. 1.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 20.....	1	Aug. 1.....	5
24.....	5	5.....	10
28.....	32	9.....	30
July 2.....	1	13.....	20
5.....	42	17.....	7
10.....	6	21.....	3
13.....	22	25.....	0
17.....	15	29.....	0
21.....	23	Sept. 2.....	1
25.....	12		
29.....	12	Total.....	247

BAND COLLECTIONS.

It would be difficult to find a more satisfactory orchard in which to conduct band-record experiments than the one used at Charlottesville in the summer of 1912. The trees used were part of an orchard

FIG. 1.—Diagram to illustrate emergence of first-brood moths of the codling moth (*Carpocapsa pomonella*) at Charlottesville, Va., in 1912.

that had not been sprayed for a number of years. Those banded were of the Winesap variety, about 18 years old, and carried a heavy crop of fruit throughout the season. In Table II are given the collections of the season and the summarized results of the rearing experiments.

TABLE II.—*Number of larvæ of the codling moth taken from the bands and reared at Charlottesville, Va., in the summer of 1912 and the spring of 1913. (See fig. 2.)*

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number of moths emerging, 1912.	Number over-wintering.	Number winter-killed.	Number of moths emerging, 1913.
June 12.....	12		12			
17.....	48	14	34			
22.....	49	11	38			
26.....	26	8	18			
July 1.....	34	11	21	2	2	
5.....	33	10	23			
9.....	26	9	17			
13.....	20	2	17	1		1
17.....	20	1	19			
21.....	34	12	22			
25.....	27	11	15	1		1
Aug. 1.....	12		4	8	2	6
5.....	20		5	15		15
10.....	23	1	1	21	2	19
13.....	26	3		23	3	20
17.....	27			27		27
21.....	37	10	1	26	16	10
25.....	30			30	15	15
29.....	45	10		35	15	20
Sept. 2.....	61	7		54	28	26
5.....	60	6		54	13	41
10.....	52	9		43		43
14.....	80	20		60	5	55
18.....	53	2		51	19	32
25.....	32	3		29	13	16
29.....	14	4		10	4	6
Oct. 2.....	2			2		2
5.....	2			2	2	
Total.....	905	164	247	494	139	335
Per cent.....	100	18.12	27.29	54.59	15.36	39.23

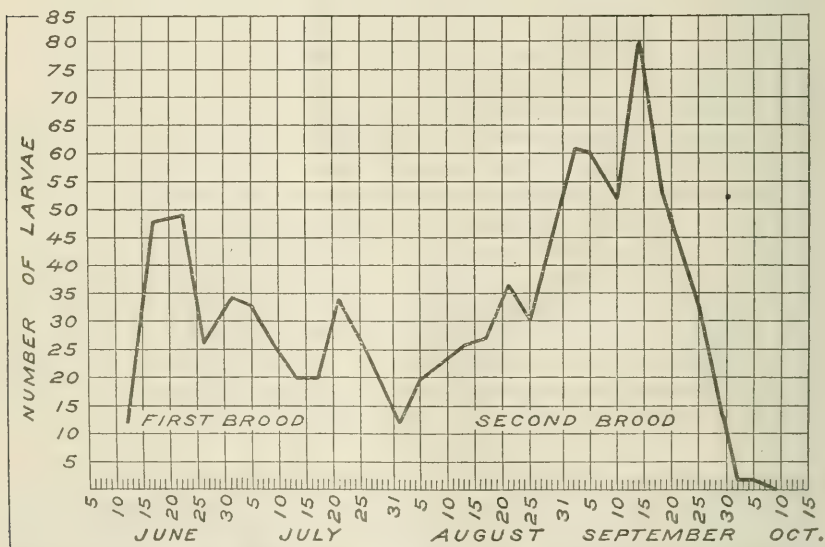


FIG. 2.—Diagram to illustrate band collections of larvæ of the codling moth at Charlottesville, Va., in 1912.

Unfortunately examinations were not begun until June 12, while larvæ were doubtless leaving the fruit as early as June 5-6. Codling-

moth larvæ appeared under the bands in considerable number throughout June and July, most of those collected previous to August 1 transforming to adults the same season. After August 1 the number of larvæ collected again increased considerably, the greater part of those taken after this date spinning up and wintering. Since summer-brood moths appeared June 20, it is reasonable to suppose that second-brood larvæ were beginning to enter the apples about July 1. If we allow a slightly longer time than has been found by other observers to be the minimum feeding period of the second brood, we might expect second-brood larvæ to be leaving the fruit by the last of July to the first of August. The fruit was picked shortly after October 5 and the records discontinued, although a few of the second brood had not finished feeding by that time.

Table II gives the results of the rearing experiments carried on with the 905 larvæ taken in the orchard in the summer of 1912. Due to handling, cannibalism, disease, etc., 18.12 per cent were lost in the rearing jars; 27.29 per cent emerged as moths that season; 54.59 per cent wintered; 15.36 per cent were winter-killed; and 39.23 per cent passed the winter and emerged as moths in the spring of 1913.

SUMMARY FOR SEASON OF 1912.

At Charlottesville in 1912 the spring-brood moths began emerging in the early part of May. First-brood larvæ began leaving the fruit the early part of June. First-brood moths began emerging June 20, allowing 10 days for egg-laying and incubation; second-brood larvæ began feeding by July 1. After August 1 most of the larvæ taken under the bands belonged to the second brood.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

The emergence records of 355 moths of the spring brood at Charlottesville in 1913 are given in Table III.

TABLE III.—*Emergence of spring-brood moths of the codling moth at Charlottesville, Va., in 1913. (See fig. 3.)*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
Apr. 18.....	2	May 21.....	21
21.....	2	24.....	21
24.....	2	27.....	11
27.....	7	30.....	10
30.....	18	June 2.....	8
May 3.....	78	5.....	8
6.....	27	8.....	1
9.....	42	11.....	1
12.....	17		
15.....	55	Total.....	355
18.....	24		

It will be remembered that the work of 1912 did not include a detailed account of the appearance of the spring brood. There was, however, very good evidence that spring-brood emergence began that season shortly after May 1. On the whole the seasonal conditions of the spring of 1913 were slightly in advance of those of 1912, and spring-brood moth emergence seems to have occurred about 10 days earlier in the former year. Moths began appearing in numbers on April 27-30, and maximum emergence was reached on May 3. Moths continued to issue in jars through May and part of June, emergence ceasing June 11. It is probable that first-brood larvæ began feeding by May 1, or 12 days after the first moth appeared in the rearing cages.

FIRST-BROOD MOTHS.

In 1913 the first of the first brood or summer brood of moths issued on June 14, from material taken under the bands in the orchard on June 5. However, emergence occurred in numbers on June 23 and reached its maximum on July 8. On the whole the graph in figure 3 probably represents fairly well the time of appearance in the orchard of the two broods of moths at Charlottesville in 1913. An occasional second-brood larva may have begun feeding by June 25, but it is probable that the insects were not entering the fruit in numbers before July 1.

TABLE IV.—*Emergence of first-brood moths of the codling moth at Charlottesville, Va., in 1913.* (See fig. 3.)

Date of obser- vation.	Number of moths emerging.	Date of obser- vation.	Number of moths emerging.
June 14.....	1	July 23.....	7
17.....	3	26.....	7
20.....	5	29.....	16
23.....	18	Aug. 1.....	7
26.....	11	4.....	2
30.....	24	7.....	2
July 2.....	26	10.....	0
5.....	26	13.....	3
8.....	40	16.....	1
11.....	21	19.....	0
14.....	28	22.....	1
17.....	10	Total.....	270
20.....	11		

BAND COLLECTIONS.

At Charlottesville, as in the other parts of the central Appalachian section, the short crop of fruit during the season of 1913 seriously interfered with the work. After the dropping, which normally follows the feeding of the first brood, not enough fruit remained to furnish food for the second-brood larvæ, and the unusually small numbers of larvæ that appeared under the bands in the latter part of the summer throw out of line completely the proportions of transforming and wintering insects. The relatively small number of overwintering larvæ given in Table V must be considered as unusual and not as evidence of what occurs under normal conditions.

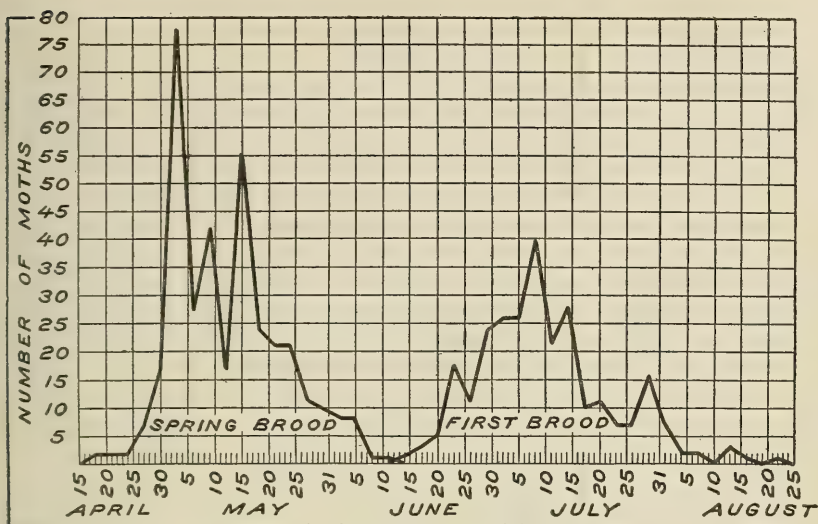


FIG. 3.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Charlottesville, Va., in 1913.

TABLE V.—Number of larvæ of the codling moth taken from bands and reared at Charlottesville, Va., in 1913. (See fig. 4.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number of moths emerging, 1913.	Number of larvæ overwintering.
June 5.....	6	2	4	.....
8.....	20	7	13	.....
11.....	33	11	22	.....
14.....	18	5	13	.....
17.....	35	19	16	.....
20.....	90	32	57	1
23.....	37	10	27	.....
26.....	54	27	25	2
30.....	85	52	31	2
July 2.....	19	8	9	2
5.....	23	3	20	.....
8.....	15	7	8	.....
11.....	10	4	5	1
14.....	8	3	4	1
17.....	10	3	7	.....
20.....	3	2	1	.....
23.....	1	.....	1	.....
26.....	5	.....	5	.....
29.....	1	.....	1	.....
Aug. 1.....	2	1	.....	1
4.....	13	10	.....	3
7.....	3	.....	.....	3
10.....	1	1	.....	.....
13.....	8	3	1	4
16.....	3	1	.....	2
19.....	6	1	.....	5
22.....	3	1	.....	2
25.....	2	.....	.....	2
28.....	9	5	.....	4
Sept. 1.....	1	.....	.....	1
3.....	1	.....	.....	1
6.....	5	1	.....	4
9.....	2	.....	.....	2
12.....	.....	.....	.....	.....
15.....	10	4	.....	6
Total.....	542	223	270	49
Percent.....	100	41.14	49.82	9.04

First-brood larvæ were taken from the bands on June 5, and continued to appear in increasing numbers through the remainder of June and most of July, the largest collection of the season occurring on June 20. Since moths of the summer or first brood appeared in the rearing cages on June 14 and in numbers by June 20, second-brood larvæ were probably entering the fruit in the field June 25-30, and, allowing a normal feeding period, must have begun to appear under the bands in the last of July to the first of August. A few larvæ were collected up to September 15, when the remaining fruit was picked and the records discontinued. Figure 4 represents graphically the numbers and time of collection of the larvæ taken from the bands during the season. In all, 542 larvæ were taken from the bands, 223,

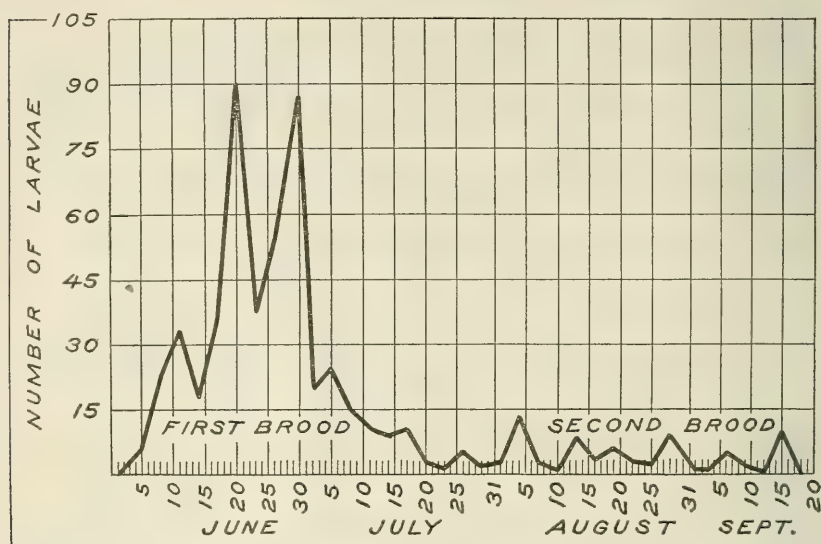


FIG. 4.—Diagram to illustrate band collections of larvæ of the codling moth at Charlottesville, Va., in 1913.

or 41.14 per cent, of which perished in the rearing cages; 49.82 per cent emerged as moths the same season, while 9.14 per cent spun up and wintered. As has already been explained, the comparative numbers of wintering and transforming larvæ given in Table V must not be considered usual. At Charlottesville in an ordinary season a large proportion of the first brood transforms, giving rise to a relatively large second brood, and with a fair crop of fruit the larvæ of the second brood taken under the bands should far exceed the first in numbers.

SUMMARY FOR SEASON OF 1913.

Spring-brood moths began emerging at Charlottesville on April 18. First-brood larvæ might be expected to have entered the fruit by April 28-30, though not in any number until several days later.

First-brood larvæ were taken under the bands June 5, and by August 1 probably most of them had left the fruit. First-brood moths appeared in the rearing cages on June 14, and in numbers June 23. Second-brood larvæ must have been entering fruit June 25-30, and were leaving by the last of July to the first of August.

INVESTIGATIONS AT GREENWOOD, VA.

DESCRIPTION OF LOCALITY.

Greenwood is situated about 18 miles west of Charlottesville, in a section of the Blue Ridge Mountains where commercial apple growing has been well established for years. In a mountain orchard section, such as this, there is considerable variation in the elevation of orchard sites. The orchard in which band-record experiments were conducted was at an altitude of about 900 feet above sea level. The work in this section for the season of 1912 is given in part only, the moth emergence of that summer being considered of sufficient importance to find a place in this report.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

Table VI contains the emergence records of 180 moths as they occurred in the rearing cages at Greenwood in 1912. The first visit of the season to Greenwood was made on May 8, and the table shows that three moths were found in the jar of wintering larvæ at that time; while these may have emerged two or three days previously, from the number appearing two days later (May 10) it can be assumed that moth emergence was just beginning on May 8.

TABLE VI.—*Emergence of spring-brood moths of the codling moth at Greenwood, Va., in 1912.* (See fig. 5.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 8.....	3	May 30.....	34
10.....	11	June 3.....	15
14.....	18	7.....	5
18.....	28		
22.....	20	Total.....	180
26.....	46		

Some time was spent in the orchard in an unsuccessful search for eggs and young larvæ, and their absence indicates that moths had at least not been appearing in the field in numbers up to that time. Maximum emergence did not occur until May 26, although moths were appearing in some numbers during all of the period from May 10 to June 3. None emerged in the rearing cages after June 7, although, had more insects been under observation, an occasional adult would probably have appeared later.

FIRST-BROOD MOTHS.

The first collection of larvæ in 1912 was delayed until June 12, though as none of those taken under the bands at the time had pupated, the beginning of first-brood moth emergence was not seriously affected thereby. In all 639 moths appeared in the rearing cages between June 23 and August 28. (See Table VII.)

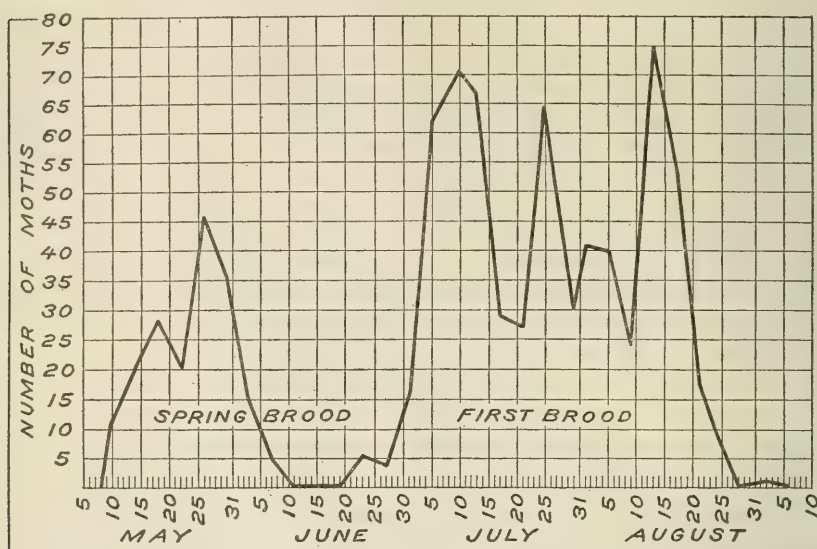


FIG. 5.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Greenwood, Va., in 1912.

TABLE VII.—Emergence of first-brood moths of the codling moth at Greenwood, Va., in 1912. (See fig. 5.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 23.....	6	Aug. 1.....	41
27.....	4	5.....	40
July 1.....	17	9.....	24
5.....	62	13.....	75
10.....	71	17.....	53
13.....	67	21.....	18
17.....	20	24.....	9
21.....	27	28.....	0
25.....	65		
29.....	30	Total.....	639

The seasonal appearance of the two broods of moths is given in figure 5.

Work at Greenwood was discontinued in 1913, the transformations of the codling moth being apparently so nearly the same as at Charlottesville that almost daily observation would be necessary to distinguish any variation at all, and according to the plan of work followed it was impossible to take records oftener than every three or four days.

INVESTIGATIONS AT HAGERSTOWN, MD.

DESCRIPTION OF LOCALITY.

Hagerstown, Md., is situated on a comparatively level portion of the lower Cumberland Valley. The country is more or less rolling, but the relative differences in altitude are not great, the actual elevation above sea level of most of this section being from 500 to 600 feet. There are a few large orchards in the vicinity, but fruit growing in a commercial way has not received much attention until recently. However, Hagerstown is not far from some very important fruit-growing districts on the east, the west, the north, and the south. Band-record experiments were carried on in this section for 1911, 1912, and 1913.

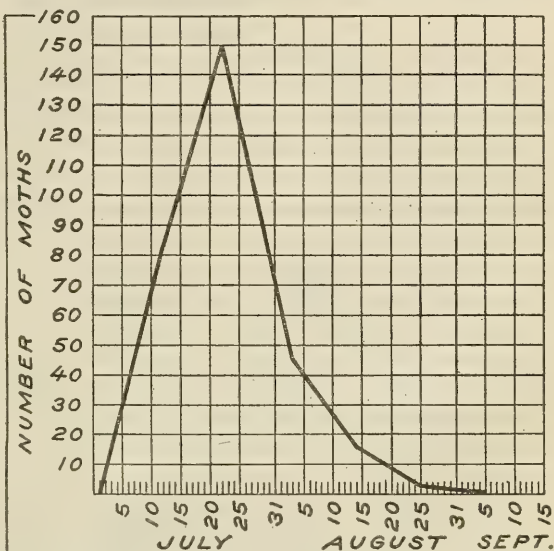


FIG. 6.—Diagram to illustrate emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1911.

INVESTIGATIONS IN 1911.

FIRST-BROOD MOTHS.

The long intervals between observations in 1911 (10 to 12 days) make the records of that year of rather doubtful value, and while they are included for Hagerstown and Pickens, it must not be understood that they are comparable in any but a general way to the data obtained in the two following years' work in these sections.

TABLE VIII.—Emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1911. (See fig. 6.)

Date of observation.	Number of moths emerging.
July 12.....	82
22.....	151
Aug. 3.....	46
11.....	16
Aug. 25.....	3
Total.....	298

The collection of larvæ from the bands, and the summer-brood moth emergence given in Table VIII, can be better appreciated by reference to figures 6 and 7, and it is doubtful if much could be added by a detailed discussion of the season's work.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

It will be noted that the records for spring-brood moth emergence given in Table IX were obtained at Smithsburg, Md., and therefore do not represent accurately what took place at Hagerstown. The Smithsburg section is 9 miles east of Hagerstown, at the foot of the Blue Ridge Mountains, and at a considerably higher elevation, and

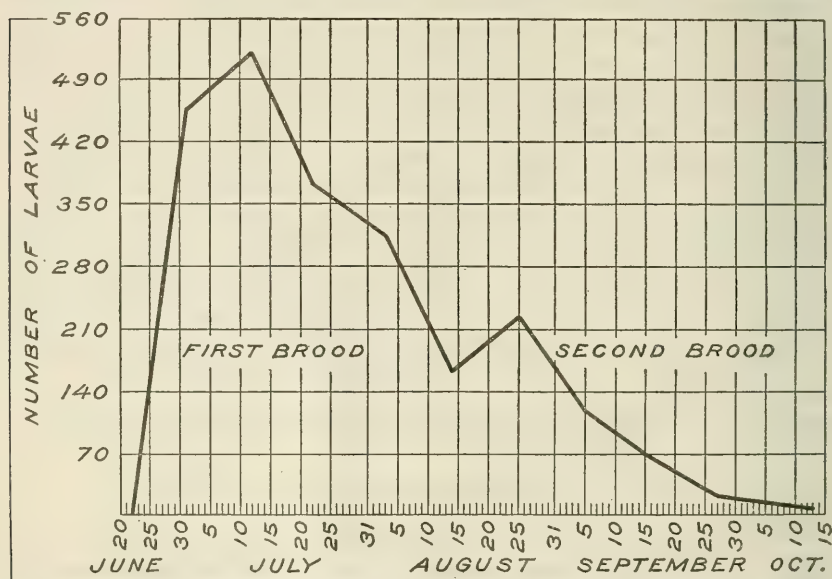


FIG. 7.—Diagram to illustrate band collections of larvæ of the codling moth at Hagerstown, Md., in 1911.

the seasonal conditions at Hagerstown are somewhat in advance of those at Smithsburg. However, no satisfactory record of moth emergence was obtained at Hagerstown in the spring of 1912, and as this was practically the only record of any value secured at Smithsburg, it is included in the report of the work in the former section.

TABLE IX.—Emergence of spring-brood moths of the codling moth at Smithsburg, Md., in 1912. (See fig. 8.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 30.....	2	June 19.....	10
June 3.....	9	23.....	4
7.....	17		
11.....	23	Total.....	85
15.....	20		

It will be seen from figure 8 that emergence began on May 30, and reached its maximum on June 11, after which time the moths decreased in numbers, ceasing to appear altogether after June 23. It would probably be safe to say that the first-brood larvæ were entering fruit by June 1, or very soon thereafter.

FIRST-BROOD MOTHS.

The emergence records of 148 moths given in Table X were obtained from the material collected in the orchard at Hagerstown and represent fairly well the occurrence of the summer or first brood of moths in the field. The 148 moths accounted for in this table comprise all that transformed during that season of the 1,706 larvæ reared, a fact

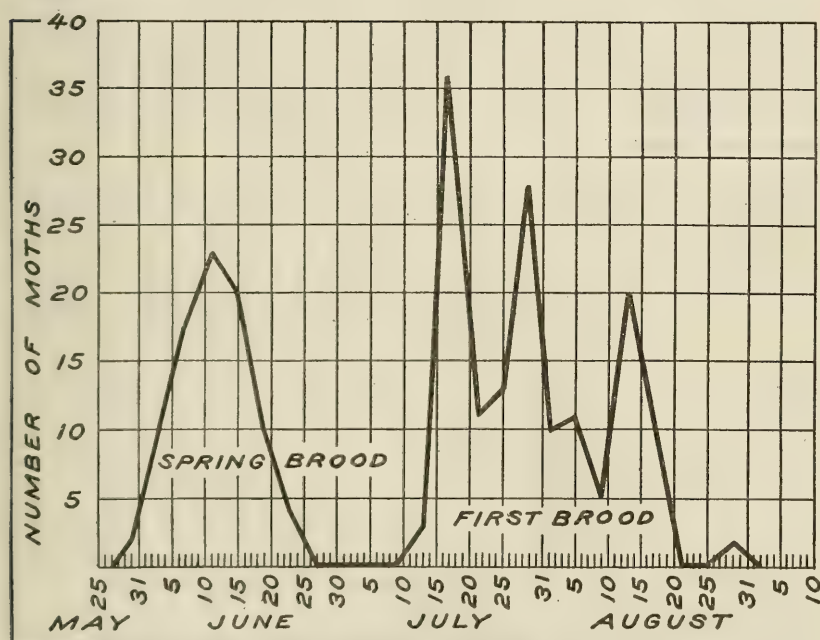


FIG. 8.—Diagram to illustrate emergence of spring-brood moths of the codling moth at Smithsburg, Md., and first-brood moths at Hagerstown, Md., in 1912.

which probably accounts for the relatively small number of second-brood larvæ that appeared under the bands later in the summer (see fig. 9).

TABLE X.—Emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1912. (See fig. 8.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 13.....	3	Aug. 13.....	20
17.....	36	17.....	9
21.....	11	21.....	.....
25.....	13	25.....	.....
29.....	28	29.....	2
Aug. 1.....	10	Total.....	148
5.....	11		
9.....	5		

First-brood moths began to emerge on July 13, and emergence continued throughout the remainder of July and the fore part of August. Two adults appeared as late as August 29, though emergence had practically ceased August 17. The codling moth is very sensitive to weather conditions, its development being especially retarded by cold, and the irregularity in the emergence curve of first-brood moths in figure 8 is due, in part at least, to extreme temperature variations of the season.

Second-brood larvæ probably began entering fruit at Hagerstown in 1912, about July 23 to 27.

BAND COLLECTIONS.

Altogether 1,706 larvæ were taken from the bands at Hagerstown in 1912. (See Table XI.) The trees used were of the York Imperial variety, about 15 years old, smooth bodied and loaded with fruit. Bands were placed in the fore part of June and examinations made every three or four days, beginning June 15.

TABLE XI.—*Number of larvæ of the codling moth taken from the bands and reared at Hagerstown, Md., during the summer of 1912 and the spring of 1913. (See fig. 9.)*

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number emerged, 1912.	Number overwintering.	Number winter-killed.	Number emerged, 1913.
June 29.....	11	4	7			
July 1.....						
5.....	58		42	16	7	9
9.....	55	24	28	3	3	
13.....	144	27	42	75	24	51
17.....	240	53	15	172	109	63
21.....	183	44	2	137	137	
25.....	207	61	10	136	100	36
29.....	228	75	2	151	112	39
Aug. 1.....	117	22		95	40	55
5.....	97	18		79	25	54
9.....	59	12		47	36	11
13.....	35	5		30	23	7
17.....	30	2		28	11	17
21.....	15	10		5		5
25.....	60	31		29	19	10
30.....	30	8		22	2	20
Sept. 2.....	48	22		26	19	7
6.....	16	9		7	7	
10.....	21	7		14	7	7
14.....	16	4		12	8	4
18.....	28	8		20	13	7
22.....	8	2		6	4	2
Total.....	1,706	448	143	1,110	706	404
Per cent.....	100	26.26	8.68	65.06	41.38	23.68

From figure 9 it will be seen that the first larvæ appeared under the bands on June 29, the numbers gradually increasing through July. From August 1 to 21 the collections decreased, increasing again slightly after the latter date, and it is probable that second-brood larvæ were beginning to leave the apples about this time. Only 8.68 per cent of the first-brood larvæ transformed to moths, which explains the relatively small second brood of larvæ shown in figure 9.

Comparison of figures 7 and 9 would suggest that, in the relative numbers of the two broods of larvæ appearing under the bands, the seasons of 1911 and 1912 were very similar.

As has already been said, only 8.68 per cent of the 1,706 larvæ taken under the bands at Hagerstown in 1912 transformed to moths that summer. The percentage of 26.26 that died in the rearing cages from handling, cannibalism, disease, immaturity, and other causes compares closely with that observed at other points, and the rearing work was evidently done with as much care and under as favorable conditions as in the localities where a much larger proportion of the first brood transformed; 65.06 per cent wintered, 41.38 per cent were winter-killed, and 23.68 per cent emerged as moths

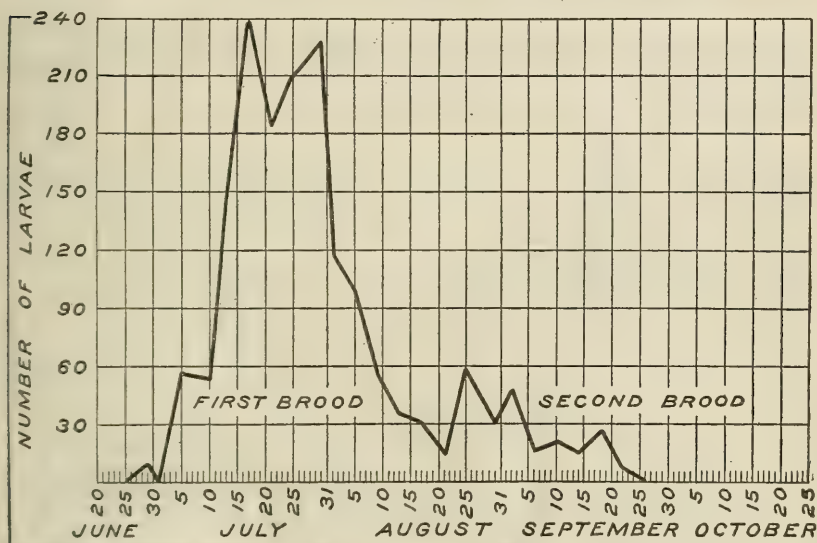


FIG. 9.—Diagram to illustrate band collections of larvæ of the codling moth at Hagerstown, Md., in 1912.

in the spring of 1913. The percentage of winter-killed larvæ at Hagerstown was much larger than in other localities that year.

SUMMARY FOR SEASON OF 1912.

Spring-brood moths began emerging in rearing cages at Smithsburg, Md., on May 30 (probably several days later than at Hagerstown). First-brood larvæ were probably entering fruit 10 to 12 days later (soon after June 1, at Hagerstown). First-brood larvæ were leaving apples in the field from June 25 to 29 to August 17 to 21.

First-brood moths began emerging from field-collected material on July 13. Second-brood larvæ probably began feeding soon after July 23, and were leaving the fruit in numbers soon after August 21.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

Table XII gives the emergence of moths of the spring brood at Hagerstown in 1913.

TABLE XII.—*Emergence of spring-brood moths of the codling moth at Hagerstown, Md., in 1913. (See fig. 10.)*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 15.....	2	June 5.....	45
18.....	6	8.....	22
21.....	12	11.....	25
24.....	9	27.....	81
27.....	38	Total.....	404
30.....	77		
June 2.....	87		

The first moths appeared in the rearing cages on May 15, but maximum emergence did not occur until May 30 to June 2. Careful

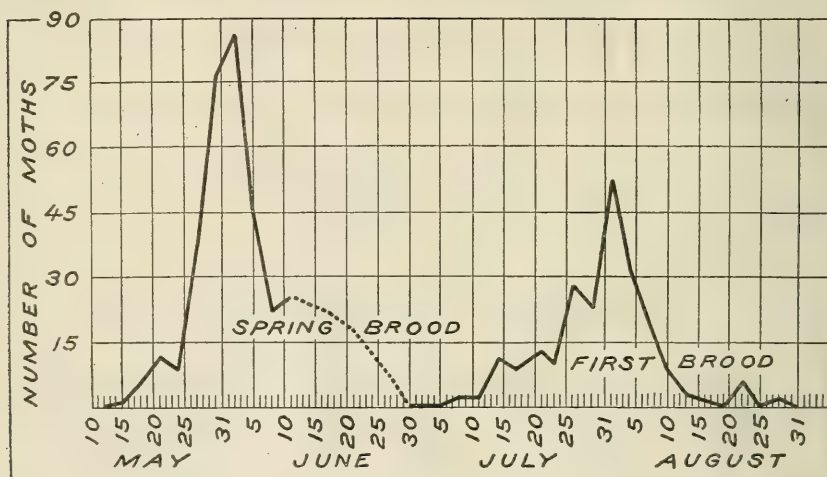


FIG. 10.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Hagerstown, Md., in 1913.

records were taken every three days up to and including June 11, but from June 11 to June 27 observations were discontinued, as indicated by the dotted line in figure 10. However, of 404 moths accounted for in Table XII, all but 81 had emerged by June 11, and the break from then until June 27 does not seriously affect the value of the records. Allowing 10 to 12 days for egg laying and incubation, first-brood larvæ were evidently beginning to feed by May 25 to 27.

FIRST-BROOD MOTHS.

The relation of the two broods of moths emerging at Hagerstown in 1913 is clearly illustrated in figure 10. Adults appeared in the rearing jars with more or less regularity from July 8 to August 10. Emergence ceased altogether on August 28. (See also Table XIII.)

TABLE XIII.—*Emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1913.* (See fig. 10.)

Date of obser- vation.	Number of moths emerging.	Date of obser- vation.	Number of moths emerging.
July 8.....	2	Aug. 7.....	20
11.....	2	10.....	8
14.....	11	13.....	3
17.....	8	16.....	1
21.....	13	19.....	0
23.....	10	22.....	6
26.....	29	25.....	0
29.....	23	28.....	2
Aug. 1.....	53	Total.....	222
4.....	31		

Probably a few second-brood larvæ were entering fruit in the field by July 20 to 25.

BAND COLLECTIONS.

In Table XIV are given the records of the collections and rearings of 2,756 larvæ taken under the bands at Hagerstown in the summer of 1913.

TABLE XIV.—*Number of larvæ of the codling moth taken from bands and reared at Hagerstown, Md., during the summer of 1913.* (See fig. 11.)

Date of collecting larvæ.		Number of larvæ collected.	Number of dead from handling, cannibal- ism, etc.	Number of moths emerging, 1913.	Number overwin- tering.
June	27.....	3	1	2	.....
	30.....	12	4	8	.....
July	2.....	38	12	17	9
	5.....	30	6	18	6
	8.....	78	19	24	35
	11.....	86	31	34	21
	14.....	136	38	41	57
	17.....	95	22	24	49
	21.....	181	53	28	100
	23.....	116	22	14	80
	26.....	150	77	7	66
	29.....	108	44	4	60
Aug.	1.....	105	40	.....	65
	4.....	73	11	1	61
	7.....	109	36	3	70
	10.....	108	27	1	80
	13.....	101	11	.....	90
	16.....	148	49	1	98
	19.....	121	41	.....	80
	22.....	110	28	.....	82
	25.....	26	6	.....	20
	28.....	128	104	.....	24
	31.....	92	16	.....	76
Sept.	3.....	203	48	.....	155
	6.....	111	34	.....	77
	9.....	127	61	.....	66
	12.....	42	8	.....	34
	15.....	32	12	.....	20
	18.....	14	4	.....	10
	21.....	18	8	.....	10
	25.....	9	5	.....	4
	27.....	17	1	.....	16
	30.....	9	3	.....	6
Oct.	3.....	5	.....	.....	5
	6.....	5	1	.....	4
	9.....	6	.....	.....	6
	12.....	2	.....	.....	2
	15.....	1	.....	.....	1
	18.....	1	.....	.....	1
Total.....		2,756	883	227	1,646
Percent.....		100	32.04	8.24	59.72

† Eaten by mice.

Larvæ began to appear on June 27, and were taken under the bands in numbers through the remainder of June, all of July, and part of August. It will be noticed that on August 25 (fig. 11) there was a sharp decrease in the number of insects collected. Considering the time first-brood moths began appearing in the rearing cages at Hagerstown, and correlating with what was taking place at Winchester and elsewhere, second-brood larvæ very likely began appear-

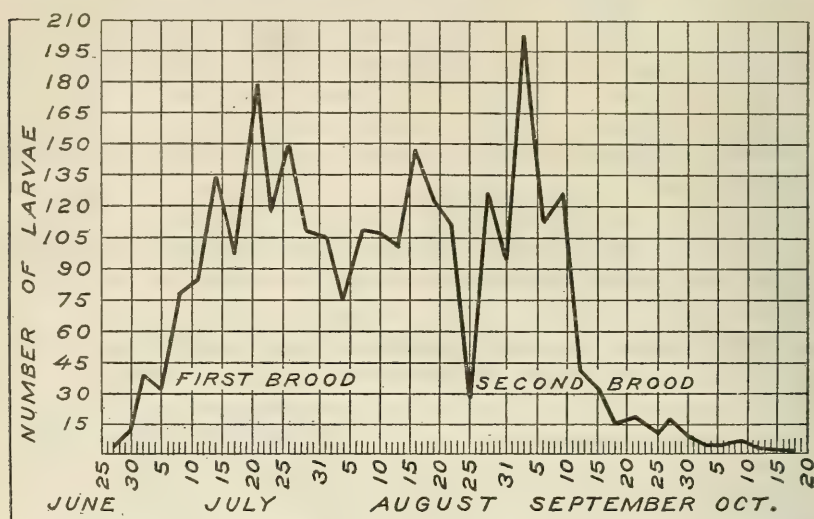


FIG. 11.—Diagram to illustrate band collections of larvæ of the codling moth at Hagerstown, Md., in 1913.

ing under the bands soon after August 25, though an unusual overlapping of the two broods of larvæ is apparent in the collections. Records were discontinued about October 25, though no larvæ appeared under the bands later than October 18.

The 8.24 per cent of transforming larvæ taken under the bands at Hagerstown in 1913 compares closely with the 8.68 per cent that transformed in 1912. The 32.04 per cent of larvæ that died from handling, cannibalism, etc., in 1913 is much higher than has usually been observed, due in part to the fact that one jar of larvæ was devoured by mice, and discarding consideration of this cage the loss is brought down to 29.37 per cent. The 59.72 per cent of wintering larvæ is only slightly less than the 65.06 per cent obtained in 1912.

SUMMARY FOR SEASON OF 1913.

Spring-brood moth emergence began May 15 and closed June 27. Allowing 10 to 12 days from emergence to hatching of first eggs, we might expect that first-brood larvæ began entering the apples May 25 to 27. First-brood larvæ appeared under the bands on June 27. First-brood moths began to emerge in the rearing cages on July 8,

though not in numbers until July 11 to 14. Second-brood larvæ were probably beginning to enter the fruit about July 20 to 25 and were leaving in numbers after August 25.

INVESTIGATIONS AT WINCHESTER, VA.

DESCRIPTION OF LOCALITY.

Winchester, the county seat of Frederick County, Va., is one of the principal shipping points for a large and well-developed apple-producing territory in the northern part of the Shenandoah Valley. The altitude of most of the country immediately surrounding Winchester varies from 650 to 800 feet above sea level; thus the relative variations in elevation are not great and the seasonal conditions are fairly uniform for the whole section. The life-history studies of the codling moth in this section for the seasons of 1912 and 1913 follow.

In Table XV are included the emergence records of 94 moths that issued at Winchester in the spring of 1912.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

TABLE XV.—*Emergence of spring-brood moths of the codling moth at Winchester, Va., in 1912. (See fig. 12.)*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 22.....	2	June 11.....	8
26.....	4	15.....	4
30.....	19	19.....	1
June 3.....	26	23.....	3
7.....	26	27.....	1
		Total.....	94

The first moth appeared in the laboratory rearing cages between May 18 and 22, though observations indicate that moths emerged several days earlier in the field. On the 24th of May eggs were rather common in the orchard, and two newly hatched larvæ were found just entering apples. Certainly moths were emerging in the field, in 1912, not later than May 15. By May 30 first-brood larvæ were observed entering fruit in the orchard in considerable numbers. The last spring-brood moth emerged June 27.

The fruit was unusually large when attacked by the codling moth in 1912, and it is of some interest to note that curculio cuts and rough spots on the apples were more frequently used by the first-brood larvæ as points of entrance than was the calyx end of the fruit.

The first of the 1912 summer or first-brood moths emerged on July 9. Eggs were laid by moths in confinement on July 13, by moths emerging during the period from July 9 to 13, but since one moth issued

July 9 it is possible oviposition began two or three days earlier in the field. Moths emerged in the rearing cages until August 21. (See Table XVI.)

FIRST-BROOD MOTHS.

TABLE XVI.—*Emergence of first-brood moths of the codling moth at Winchester, Va., in 1912.* (See fig. 12.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 9.....	1	Aug. 2.....	25
13.....	20	6.....	8
17.....	25	10.....	23
20.....	27	14.....	18
25.....	27	18.....	13
29.....	33	21.....	8
		Total.....	228

The relation of the two broods of moths can be better understood by reference to figure 12, where their seasonal appearance is represented graphically.

BAND COLLECTIONS.

An old unsprayed orchard located about a mile south of Winchester was used for the band-record experiments of 1912. The trees

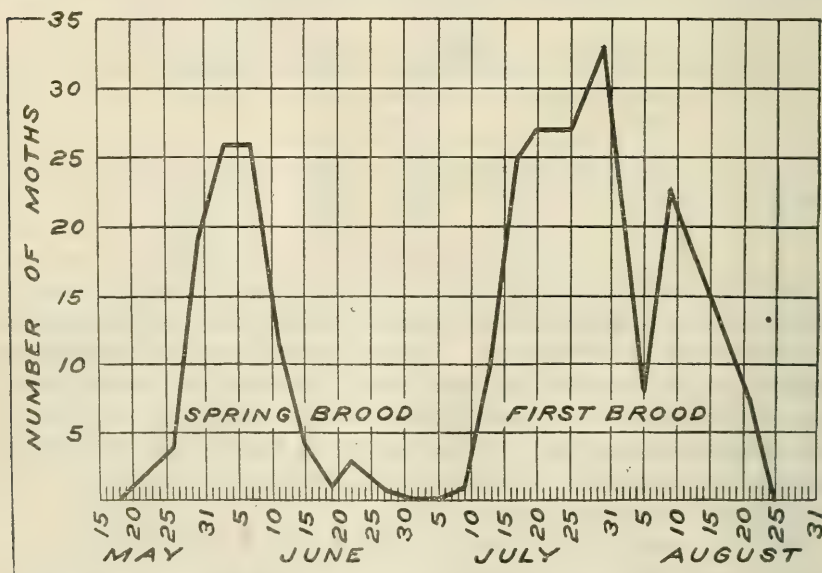


FIG. 12.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Winchester, Va., in 1912.

were of late fall and winter varieties well laden with fruit, and the infestation was very extensive, practically every apple being attacked by one or more codling-moth larvæ at some time during the season.

One larva was taken under the bands on June 19. The number collected increased throughout the remainder of June and the first half of July. By referring to figure 13 it will be noticed that during the fore part of August there occurred a series of very small collections, and about this time evidently most of the first-brood larvæ had left the fruit, while those of the second brood were still feeding. On July 15 newly hatched larvæ were observed entering fruit in the field in sufficient numbers to exclude the probability of their belonging to the first brood, especially since the last of the spring-brood moths appeared on June 27. The second-brood larvæ did not hatch in the laboratory until July 19, but this was probably three or four days behind field conditions. Allowing for a normal feeding

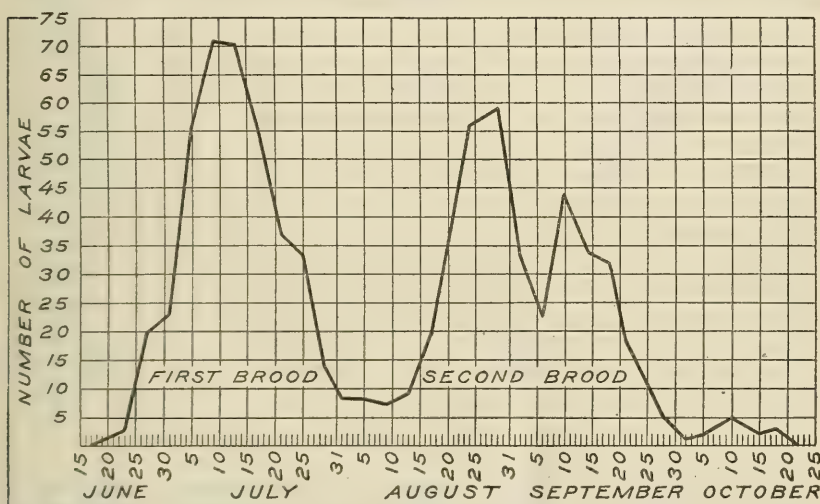


Fig. 13.—Diagram to illustrate band collections of larvæ of the codling moth at Winchester, Va., in 1912.

period, some of the second-brood larvæ should have been leaving the apples about August 9 to 13. The collections increased through the latter part of August and the first half of September. No larvæ appeared under the bands after October 18.

During the season of 1912 at Winchester 798 larvæ were taken from the bands and reared. Of these 27.19 per cent were killed in handling or were devoured by their fellows after being placed in the rearing cages; 28.57 per cent emerged as moths of the first brood; 1.38 per cent were parasitized; 42.86 per cent of the larvæ collected wintered, and 15.04 per cent were winter killed; 27.44 per cent passed the winter successfully and emerged the following season, while 0.38 per cent represents the proportion of parasites that issued in the spring of 1913. (See Table XVII.)

TABLE XVII.—*Number of larvæ of the codling moth taken from the bands and reared at Winchester, Va., during the summer of 1912 and the spring of 1913. (See fig. 13.)*

Date of collection, 1912.	Number of larvæ collected.	Number of dead from handling, cannibal- ism, etc.	Emergèd, 1912.		Number of larvæ overwin- tering.	Number of larvæ winter- killed.	Emergèd, 1913.	
			Moths.	Parasites.			Moths.	Parasites.
June 19.....	1		1					
23.....	3		3					
27.....	20	5	14		1	1		
July 1.....	23		23					
5.....	56	16	36	3	1	1		
9.....	71	24	42	4	1		1	
13.....	70	31	37	1	1		1	
17.....	56	16	31	3	6	2	4	
21.....	37	11	19		7	1	6	
25.....	33	17	11		5	1	4	
29.....	14	2	6		6		6	
Aug. 1.....	8	1	4		3		3	
5.....	8		1		7		7	
9.....	7	1			6	2	4	
13.....	9	1			8		8	
17.....	19	5			14	4	10	
21.....	37	7			30	8	21	1
24.....	56	4			52	19	33	
29.....	59	3			56	29	27	
Sept. 2.....	32	14			18	6	10	2
6.....	22	6			16	7	9	
10.....	44	17			27	15	12	
14.....	34	3			31	14	17	
18.....	32	6			26	10	16	
21.....	18	10			8		8	
25.....	11	6			5		5	
28.....	5	2			3		3	
Oct. 2.....	1				1		1	
5.....	2	1			1		1	
10.....	5	4			1		1	
15.....	2	1			1		1	
18.....	3	3						
Total.....	798	217	228	11	342	120	219	3
Per cent.....	100	27.19	28.57	1.38	42.86	15.04	27.44	0.38

SUMMARY FOR SEASON OF 1912.

Spring-brood moths began emerging in the laboratory May 18 to 22, and probably two or three days earlier in the field. First-brood larvæ began entering the fruit in the field May 24. First-brood larvæ began leaving the apples June 19. First-brood moths began emerging July 9; second-brood larvæ were observed entering fruit in the field on July 15, and a few had finished feeding by August 9 to 13.

INVESTIGATIONS IN 1913.

SPRING-BROOD AND FIRST-BROOD MOTHS.

The seasonal conditions of the spring of 1913 were considerably in advance of those of 1912, and the appearance of the spring-brood moths was correspondingly earlier. Moths appeared in numbers on May 6 and maximum emergence occurred three days later.

TABLE XVIII.—*Emergence of spring-brood moths of the codling moth at Winchester, Va., in 1913. (See fig. 14.)*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 6.....	18	June 2.....	14
9.....	38	5.....	10
12.....	6	8.....	6
15.....	16	11.....	3
18.....	30	14.....	7
21.....	29	17.....	3
24.....	8	20.....	1
27.....	16		
30.....	14	Total.....	219

Moths continued to issue in the rearing cages until June 20. The irregularity of the emergence curve in figure 14 is due in most cases

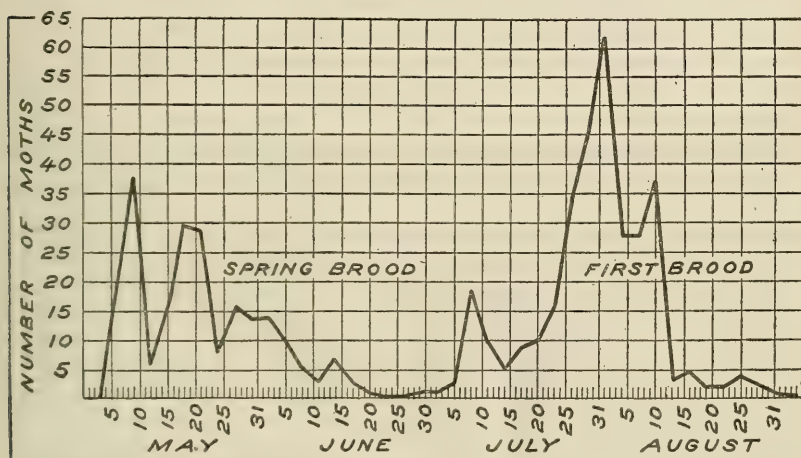


FIG. 14.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Winchester, Va., in 1913.

to fluctuations in temperature. The first moth emergence in confinement occurred 16 days earlier in 1913 than in 1912, but since adults were probably appearing in the field in 1912 not later than May 15, we may assume that spring-brood emergence began in the field only 10 to 12 days earlier in 1913.

The seasonal appearance of the two broods of moths can perhaps be best appreciated by referring to figure 14. The emergence of 326 moths of the first brood are given in Table XIX. The first adults of this brood appeared in the laboratory in 1913 on June 30, nine days earlier than in 1912. However, not until July 5 to 8 did adults appear in any numbers, and in reality the difference in the time of appearance of summer, or first-brood, moths in the two seasons is

very slight. Maximum emergence was not attained until one month later, or about August 1. The last of the first-brood moths emerged in the rearing cages on September 1.

TABLE XIX.—*Emergence of first-brood moths of the codling moth at Winchester, Va., in 1913. (See fig. 14.)*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 30.....	1	Aug. 4.....	28
July 2.....	1	7.....	28
5.....	3	10.....	37
8.....	19	13.....	3
11.....	10	16.....	5
14.....	5	19.....	2
17.....	9	22.....	2
20.....	10	25.....	4
23.....	16	29.....	2
26.....	33	Sept. 1.....	1
29.....	45		
Aug. 1.....	62	Total.....	326

BAND COLLECTIONS.

In 1913 bands were placed on 12 old apple trees in an orchard located about 2 miles south of Winchester. The rough bark was

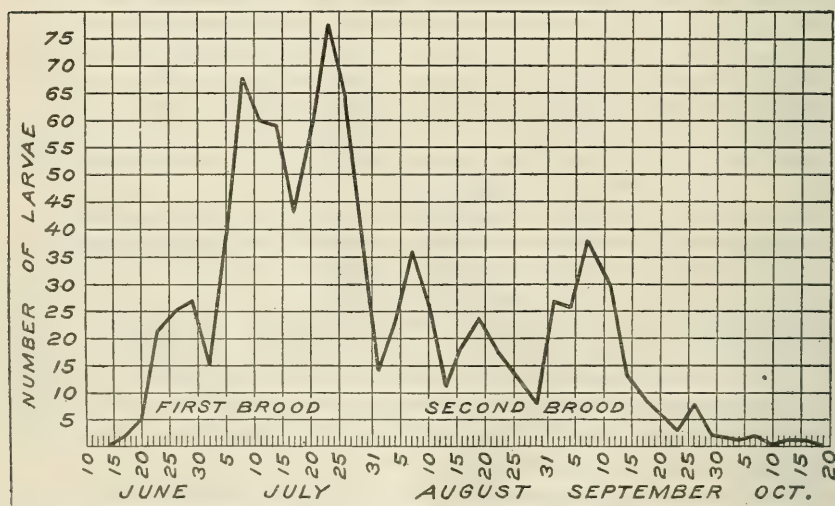


FIG. 15.—Diagram to illustrate band collections of larvæ of the codling moth at Winchester, Va., in 1913.

scraped down and other hiding places of the insect destroyed, and on the whole probably most of the larvæ that left the fruit during the season found their way under the bands. The record of collections is given in Table XX.

TABLE XX.—*Record of codling-moth larvæ taken from the bands and reared at Winchester, Va., in 1913. (See fig. 15.)*

Date of collection.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Emergèd, 1913.		Number overwintering.
			Moths.	Parasites.	
June 17.....	2	—	2	—	—
20.....	5	3	2	—	—
23.....	22	4	14	4	—
26.....	25	9	16	—	—
29.....	27	5	15	7	—
July 2.....	15	6	9	—	—
5.....	38	23	15	—	—
8.....	68	14	40	13	1
11.....	60	8	47	—	5
14.....	59	19	31	2	7
17.....	43	8	24	5	6
20.....	57	6	31	8	12
23.....	84	9	38	11	26
26.....	63	3	22	12	26
29.....	38	14	8	3	13
Aug. 1.....	14	7	3	—	4
4.....	23	6	3	—	14
7.....	36	11	3	—	22
10.....	26	9	2	—	15
13.....	11	6	1	—	4
16.....	19	9	—	—	10
19.....	24	9	—	—	15
22.....	18	9	—	—	9
25.....	14	5	—	—	9
29.....	8	2	—	—	6
Sept. 1.....	27	16	—	—	11
4.....	26	7	—	—	19
7.....	38	7	—	—	31
11.....	30	—	—	—	30
14.....	13	—	—	—	13
17.....	9	—	—	—	9
20.....	6	—	—	—	6
23.....	3	—	—	—	3
26.....	8	—	—	—	8
29.....	5	—	—	—	5
Oct. 1.....	2	—	—	—	2
4.....	1	—	—	—	1
7.....	2	—	—	—	2
10.....	—	—	—	—	—
13.....	1	—	—	—	1
16.....	1	—	—	—	1
Total.....	971	234	326	65	346
Percent.....	100	24.10	33.57	6.70	35.63

Careful examination of the bands was made, beginning about June 1, but no larvæ were taken until June 17, only two days earlier than in 1912, in spite of the fact that the first of the spring-brood moths were probably 10 to 15 days earlier than in the former season. From June 17 the collections increased until about August 1, when the numbers of insects collected decreased slightly, the proportion of those wintering increasing, and probably by August 7 to 10 most of the larvæ taken were of the second brood. The fact that the second brood did not equal the first in numbers and were somewhat irregular in their appearance under the bands is explained by the short fruit crop of the year.

Altogether 971 larvæ were collected and reared. Of this number 24.10 per cent were killed by handling, cannibalism, etc., the loss from this source being about the same as the 27.19 per cent that died from similar causes in 1912; 33.57 per cent were transformed to first-

brood moths and 6.70 per cent were parasitized. The light fruit crop already noted reduced the number of wintering larvæ to 35.63 per cent.

SUMMARY FOR SEASON OF 1913.

Spring-brood moths began to emerge May 6, and a few first-brood larvæ were probably entering the fruit by May 16. First-brood larvæ began to appear under the bands in the orchard June 17, and from these larvæ a few first-brood moths emerged in the laboratory on June 30. Second-brood larvæ were probably entering fruit in numbers by July 15; they began leaving fruit about August 13.

INVESTIGATIONS AT FISHERSVILLE, VA.

DESCRIPTION OF LOCALITY.

Fishersville is the shipping point for a part of the Shenandoah Valley, in which commercial fruit growing has for years been of considerable importance. While in approximately the same latitude as Charlottesville, the seasonal conditions of this section are decidedly different chiefly on account of the much higher altitude; in fact, there is a much greater similarity of conditions between Fishersville and Winchester, both of which are in the Shenandoah Valley, than between Fishersville and Charlottesville, between which two points the Blue Ridge Mountains intervene. Differences in humidity and other climatic conditions occur between these two regions that may effect the development of the codling moth and that may not be entirely accounted for by differences in altitude. The band-record experiments were carried on in locations 1,400 to 1,500 feet above sea level, which is probably about the average elevation of orchards in this section.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

In a limited way the emergence dates of 119 moths given in Table XXI probably represent fairly well the occurrence of the spring brood at Fishersville in 1912. The rearing material was collected from the bands in the fall of 1911.

TABLE XXI.—*Emergence of spring-brood moths of the codling moth at Fishersville, Va., in 1912.* (See fig. 16.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 18.....	5	June 15.....	1
22.....	13	19.....	
26.....	14	23.....	
30.....	42	27.....	1
June 3.....	27		
7.....	5	Total.....	119
11.....	11		

Emergence began on May 18 and reached its highest numbers on May 30, 12 days later. However, since first-brood larvæ appeared under the bands on June 11, it is probable that moths emerged in the field several days prior to May 18. The moths continued to emerge through the remainder of May and in lessening number through the most of June, ceasing to appear altogether after June 27.

The records of the appearance of 273 moths of the first brood that issued from band-collected material at Fishersville in the summer of 1912 are given in Table XXII.

FIRST-BROOD MOTHS.

TABLE XXII.—*Emergence of first-brood moths of the codling moth at Fishersville, Va., in 1912. (See fig. 16.)*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 2.....	5	Aug. 1.....	15
5.....	7	5.....	13
9.....	35	9.....	16
13.....	30	13.....	1
17.....	55	17.....	3
21.....	35	21.....	1
25.....	31		
29.....	26	Total.....	273

The work at Fishersville in 1912 was carried on under very ideal conditions, and July 2, the time when the first-brood moths began emerging in the rearing cages, represents field conditions as nearly as is possible with band-collected rearing material. The time of first appearance for the first-brood moths was seven days in advance of Winchester, while between the first emergence of spring-brood moths there was a four-day difference in the two sections.

Moths appeared in numbers through July and the first half of August, attaining their maximum on July 17. The last moth appeared in the rearing cages on August 21. The relative time of appearance of the two broods of moths at Fishersville in 1912 is shown in figure 16.

BAND COLLECTIONS.

About 12 smooth-bodied young York Imperial and Ben Davis apple trees were banded at Fishersville in 1912. On the whole the records given in Table XXIII and figure 17 represent fairly well the time the two broods of larvæ were leaving the fruit that season. Three larvæ were taken under the bands on July 11 and the number increased in the succeeding collections until about July 1, when the number gradually decreased until the fore part of August. By August 1 a large part of the first brood had left the fruit, as is evidenced in the band-record curve of figure 17.

Since first-brood moths emerged in the rearing cages on July 2, larvæ hatching from eggs laid by these moths might reasonably be expected to begin feeding by July 12 to 15. After August 9 the

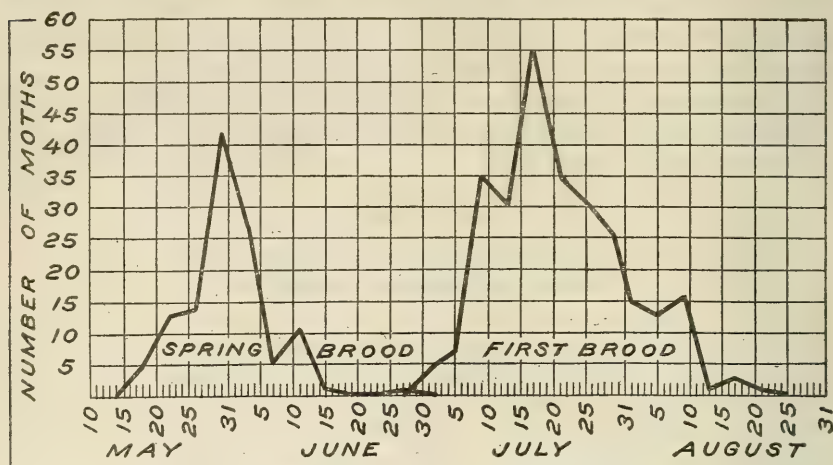


FIG. 16.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Fishersville, Va., in 1912.

collections increased to the middle of September. Second-brood larvæ continued to appear under the bands until November 1, when the fruit was picked and the records discontinued.

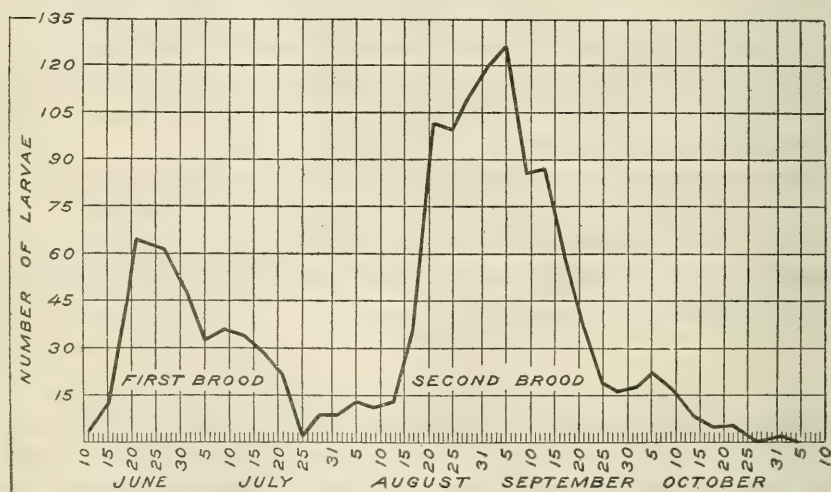


FIG. 17.—Diagram to illustrate band collections of larvæ of the codling moth at Fishersville, Va., in 1912.

In Table XXIII are recorded the numbers of larvæ taken in the orchard at different dates through the season. Altogether 1,418 larvæ were collected and reared, of which 12.90 per cent were killed

by handling or devoured by their fellows in the rearing cages; 19.96 per cent emerged as adults during the summer of 1912; 67.14 per cent wintered and 24.19 per cent were winter killed; and 42.95 per cent emerged as moths in the spring of 1913.

TABLE XXIII.—*Number of larvæ of the codling moth taken from the bands and reared at Fishersville, Va., during the summer of 1912 and the spring of 1913. (See fig. 17.)*

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from cannibalism, etc.	Number of moths emerging, 1912.	Number of larvæ overwintering.	Number of larvæ winter killed.	Number of moths emerging, 1913.
June 11.....	3	1	2			
15.....	12	3	9			
19.....	43	13	30			
21.....	64	41	23			
27.....	61	11	50			
July 1.....	48	14	34			
5.....	32	5	27			
9.....	35		28	7		7
13.....	34	3	28	3		3
17.....	29		23	6		6
21.....	22	2	16	4		4
25.....	1		1			
29.....	9	1	2	6		6
Aug. 1.....	9		5	4	2	2
5.....	14		4	10		10
9.....	11	1	1	9		9
13.....	13	2		11	9	2
17.....	36			36	12	24
21.....	101	2		99	46	53
25.....	100	17		83	43	40
28.....	109	14		95	44	51
Sept. 1.....	120	23		97	34	63
5.....	127	15		112	39	73
9.....	86	6		80	28	52
13.....	88	2		86	37	49
17.....	61	2		59	32	27
21.....	37			37	11	26
25.....	19			19		19
28.....	16			16	3	13
Oct. 2.....	18			18		18
5.....	22	3		19		19
9.....	17	1		16	3	13
14.....	8			8		8
18.....	5			5		5
22.....	6	1		5		5
Nov. 1.....	2			2		2
Total.....	1,418	183	233	952	343	609
Percent.....	100	12.90	19.96	67.14	24.19	42.95

SUMMARY FOR SEASON OF 1912.

Spring-brood moths began emerging in the laboratory May 18 and probably several days earlier in the field. Ten to 12 days later first-brood larvæ were probably beginning to enter fruit. First-brood larvæ began leaving the fruit June 11. First-brood moths emerged July 2 to August 21, and second-brood larvæ probably were entering fruit by July 12. Soon after August 5 to 9 the number of larvæ appearing under the bands increased, and most of the larvæ taken after this date may be considered to be of the second brood.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

Figure 18 represents the occurrence of 608 moths of the spring brood that appeared in the rearing cages at Fishersville in 1913. Moths emerged first on May 3, but maximum emergence was delayed until May 30, the emergence curve in figure 18 for Fishersville being very different in this respect from the spring-brood curve at Winchester, as it appears in figure 14. Adults continued to emerge until June 27. (See also Table XXIV.)

TABLE XXIV.—*Emergence of spring-brood moths of the codling moth at Fishersville, Va., in 1913. (See fig. 18.)*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 3.....	6	June 5.....	44
6.....	1	8.....	10
9.....	3	11.....	9
12.....	9	14.....	22
15.....	11	17.....	10
18.....	53	20.....	7
21.....	28	24.....	3
24.....	94	27.....	2
27.....	91	Total.....	608
30.....	124		
June 2.....	81		

First-brood larvæ were probably entering the fruit in the field by May 10 to 13, from eggs laid by moths emerging May 1 to 3.

On account of the light crop of fruit in 1913 the records at Fishersville for the remainder of the season are of little value and are not included in this report

INVESTIGATIONS AT FRENCH CREEK, W. VA.

DESCRIPTION OF LOCALITY.

French Creek is located near the lower border of the Transition Life Zone in a hilly region not far from the center of West Virginia. Commercial apple growing is just beginning to attract attention, and several orchards of considerable size are being planted in that general locality. Bearing orchards of from 5 to 25 acres are not uncommon. The orchards from which banding records were obtained are located at an approximate elevation of 1,600 feet above the level of the sea.

INVESTIGATIONS IN 1911.

On June 19, 1911, 15 suitable apple trees in an orchard that had never been sprayed were banded, but it was found that the bands were placed too late in the season to obtain a complete record of the time of emergence from the fruit of the first-brood larvæ. The bands

furnished a supply of wintering larvæ to be used for emergence records of the spring brood of moths in 1912.

Predaceous and parasitic enemies of the codling moth were possibly more abundant here than in any other orchard in which banding records were made during the investigation. The second-brood larvæ were very extensively parasitized by hairworms (*Mer-mis* sp.). Of the larvæ of this brood, 71 out of 159, or nearly 50 per cent, died from this cause.

The first-brood moths began to appear in the jars on July 5, when five were found. The maximum was reached on July 8, and from that time the numbers gradually diminished until September 13, when the last two of the season appeared.

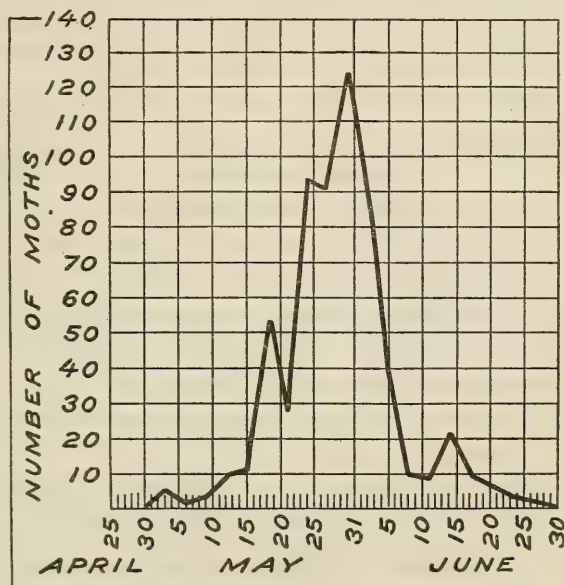


FIG. 18.—Diagram to illustrate emergence of spring-brood moths of the codling moth at Fishersville, Va., in 1913.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

On account of the high mortality, due to parasites and other causes, only about 50 wintering larvæ were alive to pupate in the spring. Pupation took place from April 22 to 28.

TABLE XXV.—Emergence of spring-brood moths of the codling moth at French Creek, W. Va., in 1912. (See fig. 19.)

Date of obser- vation.	Number of moths emerging.	Date of obser- vation.	Number of moths emerging.
May 13.....	1	May 25.....	16
14.....	2	29.....	4
16.....	3	June 1.....	2
21.....	8	Total.....	36

Table XXV shows that the first moths of this brood issued on May 13, the last on June 1, and the greatest number on May 25. The last petals were dropping from apple on May 10, so that the first moth

appeared 3 days after the blossoms were off and the maximum moth emergence occurred from 10 to 12 days later.

FIRST-BROOD MOTHS.

As indicated in Table XXVI, first-brood moths made their appearance in the jars on July 20, when seven were found. The number increased up to July 28, and from that date until August 17 maximum

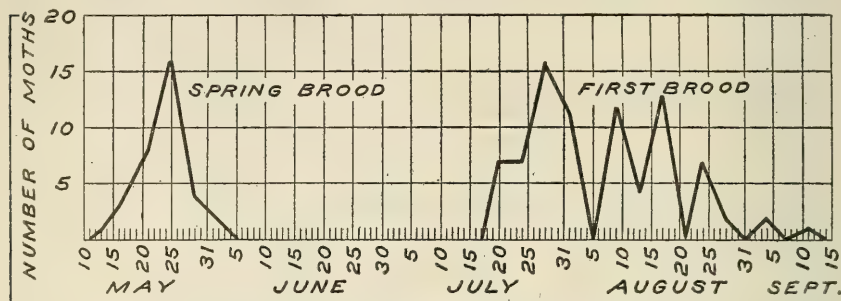


FIG. 19.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at French Creek, W. Va., in 1912.

numbers appeared. After the latter date the numbers decreased until September 11, when the last one issued.

TABLE XXVI.—*Emergence of first-brood moths of the codling moth at French Creek, W. Va., in 1912. (See fig. 19.)*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 20.....	7	Aug. 24.....	7
24.....	7	28.....	2
28.....	16	31.....	2
Aug. 1.....	11	Sept. 4.....	2
5.....	12	7.....	1
9.....	4	11.....	
13.....	13	Total.....	82
17.....			
21.....			

BAND COLLECTIONS.

About the middle of June, 12 apple trees were banded in an old orchard that had never been sprayed. The bands were examined twice each week. This year the larvæ were later by at least a week in beginning to leave the fruit than in 1911. The extent and dates of the collections are set forth in Table XXVII and figure 20.

TABLE XXVII.—*Record of codling-moth larvæ collected under bands at French Creek, W. Va., during the season of 1912. (See fig. 20.)*

Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.
June 24..	2	Aug. 5...	7	Sept. 18...	20
26..	0	9...	8	21...	22
29..	2	13...	10	25...	24
July 3...	5	17...	12	28...	13
6...	7	21...	12	Oct. 2...	8
10...	19	24...	6	5...	14
13...	12	28...	7	9...	8
17...	16	31...	5	12...	5
20...	10	Sept. 4....	17	16...	2
24...	16	7....	11		
28...	13	11....	10	Total.	339
July 31....	5	14....	11		

The first two larvæ were found on June 24. After June 26 the numbers increased with each collection until July 10. From that

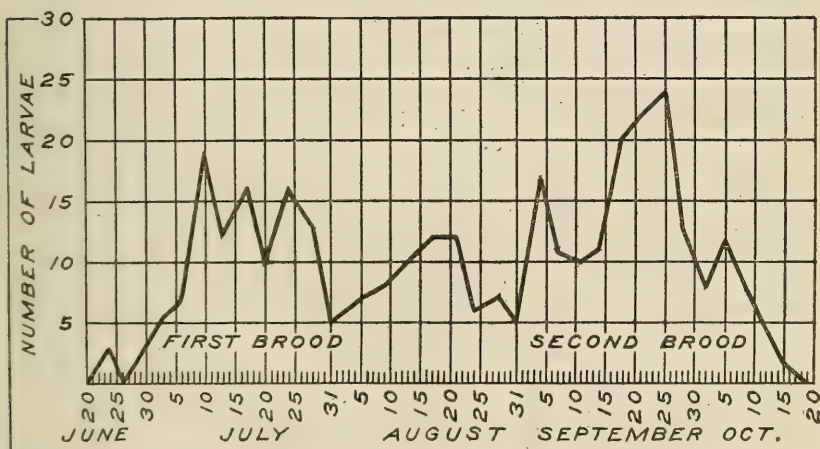


FIG. 20.—Diagram to illustrate band collections of codling moth larvæ at French Creek, W. Va., in 1912.

date until July 28 the size of the collections remained fairly constant. Collections were smaller from July 31 to August 13, after which time they increased until September 25, decreasing thereafter until October 16, when the last two were taken.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

The details of the spring-brood moth emergence are set forth in Table XXVIII and are also shown graphically in figure 21.

TABLE XXVIII.—*Emergence of spring-brood moths of the codling moth at French Creek, W. Va., in 1913. (See fig. 21.)*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 6.....	1	June 7.....	11
10.....	11	10.....	0
13.....	4	14.....	8
17.....	18	17.....	6
20.....	25	21.....	5
24.....	4	24.....	2
27.....	11		
31.....	9	Total.....	134
June 3.....	19		

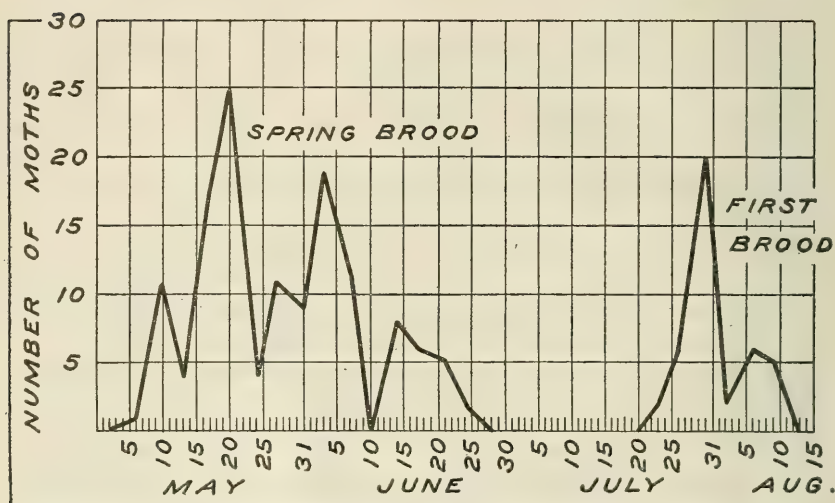


FIG. 21.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at French Creek, W. Va., in 1913.

The first moth was found in the jars on May 6, the maximum numbers from May 17 to June 7, and the last on June 24. A freeze occurring on the night of April 20 caught the apple trees just coming into full bloom, practically destroying the entire crop of blossoms. The first moth appeared 16 days after the date of the freeze, and the maximum emergence was a little more than four weeks after the freeze.

FIRST-BROOD MOTHS.

Owing to the light crop of apples only a few larvæ were obtained, and the number of first-brood moths emerging was insignificant. Table XXIX shows the number that were obtained.

TABLE XXIX.—*Emergence of first-brood moths of the codling moth at French Creek, W. Va., in 1913.* (See fig. 21.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 23.....	2	Aug. 6.....	6
26.....	6	9.....	5
30.....	20		
Aug. 2.....	2	Total.....	41

It will be seen from this table that only 41 first-brood moths were obtained. Of these the first emerged on July 23, the maximum number on July 30, and the last on August 9.

BAND COLLECTIONS.

A period of cold, occurring April 20 and 21, when the temperature dropped to 20° F., followed by another drop to 25° F. on the night of May 10, destroyed practically all the apple crop in the locality. One old orchard containing a few bearing trees that were not sprayed was found and eight of the trees were banded on July 1. Table XXX shows the number of larvæ collected under these bands.

TABLE XXX.—*Record of codling-moth larvæ collected under bands at French Creek, W. Va., in 1913.*

Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.
July 5.....	6	Aug. 6.....	6	Sept. 6.....	4
9.....	17	9.....	4	10.....	1
12.....	19	13.....	7	13.....	2
16.....	18	15.....	6	17.....	2
19.....	5	20.....	7	20.....	0
23.....	8	23.....	6	24.....	1
26.....	10	27.....	4		
30.....	3	30.....	4	Total.....	143
Aug. 2.....	1	Sept. 3.....	2		

This table shows that the first larvæ were found under the bands on July 5, the greatest number, which was 19, on July 12, and the last on September 24. The second-brood larvæ were few in number, the collections being nearly uniform from August 6 to 23, after which time they decreased until the last was found.

INVESTIGATIONS AT PICKENS, W. VA.

DESCRIPTION OF LOCALITY.

The orchard at Pickens in which banding records were obtained in 1911 and 1912 is located in a mountainous region at an elevation of 3,500 feet above the level of the sea. The native flora and fauna of the immediate locality indicate the junction of the Transition and

Canadian Life Zones. Fruit growing is not extensively engaged in, although a considerable quantity of apples is produced and disposed of in lumber camps and other local markets.

The codling moth was less abundant here than in other localities where banding records were made. This was probably due to the higher elevation and the consequently shorter breeding season. Data were collected only in 1911 and 1912, the apple crop being an entire failure in 1913.

INVESTIGATIONS IN 1911.

On the 22d of June, 18 apple trees were banded in the orchard of Mr. Lewis Wunchner, 4 miles southeast of the village of Pickens.

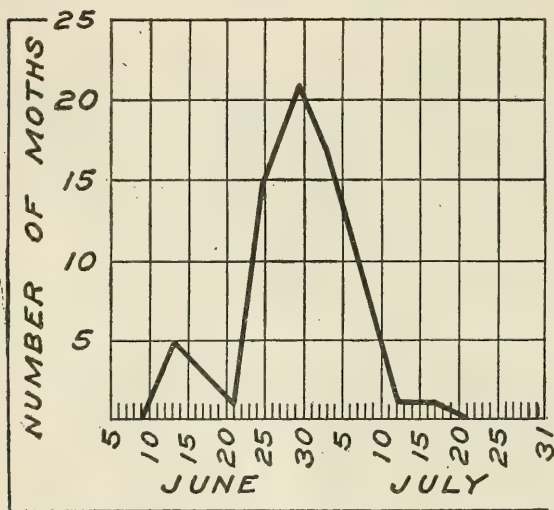


FIG. 22.—Diagram to illustrate emergence of spring-brood moths of the codling moth at Pickens, W. Va., in 1912.

The orchard had never been sprayed and most of the trees banded were bearing heavy crops of fruit.

BAND COLLECTIONS.

The first larvæ were found under the bands on July 7, on which date 27 were collected. The maximum number were found on July 19. The last were found on September 29, at which time the fruit was gathered from the trees by the owner of the orchard.

The number of larvæ found had dropped from 75, on September 11, to 17 on September 29, and it is probable that only a few more individuals would have gone under the bands had the fruit remained on the trees longer. The details of the band collections are shown more fully in Table XXXI.

TABLE XXXI.—Record of codling-moth larvæ and pupæ collected under bands at Pickens, W. Va., in 1911.

Date of collection.	Number of larvæ.	Number of pupæ.	Total.	Number of larvæ wintering.	Per cent of larvæ wintering.
July 7.....	27	.....	27	.....	.....
19.....	82	36	118	4	3.5
29.....	36	7	43	6	13.9
Aug. 8.....	23	6	29	15	51.7
18.....	58	3	61	47	77
28.....	28	1	29	23	79.3
Sept. 11.....	75	.....	75	75	100
29.....	17	.....	17	17	100
Total number collected.....			399		

FIRST-BROOD MOTHS.

Table XXXII shows that of the 59 first-brood moths reared the first were found in the breeding jars on July 29, the maximum numbers from August 8 to 28, and the last on September 11.

TABLE XXXII.—*Emergence of first-brood moths of the codling moth at Pickens, W. Va., during the season of 1911.*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 29.....	14	Aug. 28.....	5
Aug. 8.....	20	Sept. 11.....	1
18.....	19	Total.....	59

INVESTIGATIONS IN 1912.

In 1912 the same orchard was used for the banding records as in 1911, although in most cases different trees were banded. Twelve trees were used.

SPRING-BROOD MOTHS.

Table XXXIII indicates the numbers and dates of emergence of this brood of moths at Pickens.

TABLE XXXIII.—*Emergence of spring-brood codling moths at Pickens, W. Va., during the season of 1912. (See fig. 22.)*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 13.....	5	July 3.....	17
17.....	3	8.....	8
21.....	1	12.....	1
25.....	15	17.....	1
29.....	21	Total.....	72

Moths from the larvæ that had wintered in the rearing jars did not begin to emerge until nearly the middle of June, as is shown in the table. The first were found in the jars on June 13, the greatest numbers from June 25 to July 3, and the last on July 17.

BAND COLLECTIONS.

Larvæ were exceedingly scarce, as is shown in Table XXXIV, only 47 being taken under the bands during the entire season. The first was found on July 24 and the last on October 5. The numbers are so few that no distinct line can be drawn between the first and second broods.

TABLE XXXIV.—*Record of codling-moth larvæ collected under bands at Pickens, W. Va., during the season of 1912.*

Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.
July 24..	1	Aug. 24..	2	Sept. 18..	7
30..	2	28..	1	21..	1
Aug. 5..	2	31..	4	25..	5
10..	2	Sept. 4..	3	28..	5
14..	1	7..	2	Oct. 5..	2
17..	1	11..	5	Total..	47
21..	2	14..	1		

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

Of the 47 larvæ collected in 1912, 28 wintered and transformed to moths in 1913. Table XXXV shows the time of emergence.

TABLE XXXV.—*Emergence of spring-brood codling moths at Pickens, W. Va., during the season of 1913.*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 21.....	0	July 1.....	8
24.....	8	5.....	4
28.....	8	8.....	0
		Total.....	28

The jars in which the larvæ had wintered were examined twice a week and on June 24 eight moths, which were the first of the season, were found. The same number were found on June 28, and also on July 1. The last were found on July 5.

RÉSUMÉ OF REARING EXPERIMENTS IN MARYLAND, VIRGINIA, AND WEST VIRGINIA.

Tables XXXVI and XXXVII summarize the rearing experiments of 1912 and 1913 in the different localities.

TABLE XXXVI.—*Résumé of rearing experiments on the codling moth at five points in Virginia, West Virginia, and Maryland in 1912.*

Observation.	Hagers-town, Md.		Winches-ter, Va.		Fishers-ville, Va.		Charlottes-ville, Va.		French Creek, W. Va.		Total.	
	Num-ber.	Per cent.	Num-ber.	Per cent.	Num-ber.	Per cent.	Num-ber.	Per cent.	Num-ber.	Per cent.	Num-ber.	Per cent.
Larvæ collected.....	1,706	100.00	798	100.00	1,418	100.00	905	100.00	339	100.00	5,166	100.00
Larvæ dying from hand-ling, cannibalism, etc. . .	448	26.26	217	27.19	183	12.90	164	18.12	80	23.60	1,092	21.12
Moths reared same season . .	148	8.68	228	28.57	283	19.96	247	27.29	82	24.19	988	19.12
Moths reared following sea-son . . .	404	23.68	219	27.44	609	42.95	355	39.23	134	39.53	1,721	33.31
Wintering larvæ.....	1,110	65.06	342	42.86	952	67.14	494	54.59	172	50.74	3,070	59.42
Winter-killed larvæ.....	706	41.38	120	15.04	343	24.19	139	15.36	38	11.21	1,346	26.06
Parasitized larvæ.....			14	1.76					5	1.47	19	.36

TABLE XXXVII.—*Résumé of rearing experiments on the codling moth at four points in Virginia, West Virginia, and Maryland in 1913.*

Observation.	Hagerstown, Md.		Winchester, Va.		Charlottesville, Va.		French Creek, W. Va.		Total.	
	Num-ber.	Per-cent.	Num-ber.	Per-cent.	Num-ber.	Per-cent.	Num-ber.	Per-cent.	Num-ber.	Per-cent.
Larvæ collected.....	2,756	100.00	971	100.00	542	100.00	143	100.00	4,412	100.00
Larvæ dying from handling, cannibalism, etc.....	883	32.04	234	24.10	223	41.14	48	33.58	1,388	31.46
Moths emerging same season.....	227	8.24	326	33.57	270	49.82	41	28.67	864	19.58
Wintering larvæ.....	1,646	59.72	346	35.63	49	9.04	51	35.66	2,092	47.38
Parasitized larvæ.....			65	6.70			3	2.09	68	1.55

It will be noted that the proportion of larvæ dying in the rearing cages, due to handling, cannibalism, disease, etc., varied from 12.90 per cent to 41.14 per cent. The latter figure, however, is unduly high, the average loss from this source being 21.12 per cent in 1912 and 31.46 per cent in 1913. The proportion of larvæ transforming the same season as that in which they were collected varied from 8.24 per cent at Hagerstown to 49.82 per cent at Charlottesville, with an average of 19.12 per cent in 1912 and 19.58 per cent in 1913. For 1912 from 42.86 per cent to 67.14 per cent of all larvæ collected spun up and wintered, the average for all points being 59.42 per cent. The proportion of wintering larvæ in 1913 was abnormally small on account of the light fruit crop of that year. Loss from winter killing amounted to from 11.21 per cent to 41.38 per cent, the average for all points being 26.06 per cent. Observations on parasitism were made only at Winchester and French Creek, the highest recorded being 6.70 per cent at Winchester in 1913. It must be remembered, however, that the foregoing facts are taken from observations of insects kept in confinement, and only in a limited way indicate what occurs under normal out-of-door conditions.

Table XXXVIII gives the numbers of codling-moth larvæ collected and reared in the course of the work in the different localities.

TABLE XXXVIII.—*Number of codling-moth larvæ collected and reared in the different localities in Virginia, Maryland, and West Virginia during 1911, 1912, and 1913.*

Locality.	Year.	Number of larvæ collected and reared.	Locality.	Year.	Number of larvæ collected and reared.
Charlottesville, Va.....	1911	1,218	Hagerstown, Md.....	1911	1,761
	1912	905		1912	1,706
	1913	542		1913	2,756
Greenwood, Va.....	1911	1,979	French Creek, W. Va.....	1911	633
	1912	1,862		1912	339
Fishersville, Va.....	1911	910	Pickens, W. Va.....	1913	143
	1912	1,418		1911	399
Winchester, Va.....	1911	2,079		1912	47
	1912	798	Total.....		20,466
	1913	971			

NUMBER OF FIRST-BROOD LARVÆ TRANSFORMING FIRST SEASON.

Table XXXIX shows the numbers of transforming and wintering band-collected larvæ of the first brood for several localities. These data are tabulated for their value in determining the relative size of the second brood of larvæ.

TABLE XXXIX.—*Number of first-brood larvæ of the codling moth transforming to moths the first season.*

Locality.	Year	Number of first-brood larvæ living to transform.	Number of first-brood larvæ transforming first season.	Per cent transforming first season.	Number of first-brood larvæ wintering.
Charlottesville, Va.....	1912	259	247	95.37	12
Do.....	1913	278	269	96.76	9
Hagerstown, Md.....	1912	1,122	147	13.19	974
Do.....	1913	1,356	227	16.74	1,129
Fishersville, Va.....	1912	308	278	90.26	30
Winchester, Va.....	1912	266	228	85.71	38
Do.....	1913	476	325	68.28	151
Keyser, W. Va.....	1911	226	221	97.78	5
French Creek, W. Va.....	1911	202	201	99.50	1
Do.....	1912	93	81	87.10	12
Pickens, W. Va.....	1911	154	59	38.31	95
Total.....		4,740	2,284	48.19	2,456

Since an indeterminate number of larvæ always die in the jars on account of artificial conditions, only those that lived to emerge as moths are considered in this table. It will be seen that there is a great variation in the percentage of the larvæ wintering in the different localities, and that in no case did all the first-brood larvæ transform to moths the first season. At Charlottesville, Fishersville, Keyser, and French Creek the proportion transforming the first season was so great as to insure nearly a full second brood of larvæ, while at Hagerstown and Pickens the large proportion wintering would indicate only a partial or scant second brood.

Where the banded orchards were bearing a full crop of fruit and other conditions were favorable for normal development of the larvæ, the relative sizes of the first-brood and second-brood band collections support the conclusions to be drawn from the data given in the table.

EFFECT OF DIFFERENCES IN ALTITUDE AND LATITUDE UPON THE DEVELOPMENT OF THE CODLING MOTH.

The stations at which the codling-moth rearing work reported in this paper was conducted comprise a range in altitude of 3,100 feet and in latitude of practically $1^{\circ} 40'$, or about 115 statute miles. In correlating the data from the various stations an effort has been made to determine whether or not definite differences in altitude and latitude have a corresponding and constant effect on the time of metamorphic changes in this species of insect. The results indicate

that the codling moth in its development is so responsive to transient weather conditions and other local disturbing factors that the time of appearance of a certain brood in one locality can not be determined with certainty by any mathematical calculation based on the known time of appearance of the same brood in another locality of a known difference in altitude or latitude. It is probable that local differences in humidity, susceptibility to sudden changes in temperature as effected by topography, and, possibly, soil conditions, are more or less direct factors influencing the time of developmental changes in the insect.

In Table XL the results of these observations are given. In this table use is made of the law laid down some years ago by Dr. A. D. Hopkins that in phenological phenomena a fourth of a degree of latitude, or 100 feet in altitude, is equal to one day of time. The table shows that in this particular case the law does not apply. Charlottesville, being at the lowest altitude and the most southerly of the stations, is taken as a base and the other points considered in their relation thereto. In considering this table it should be borne in mind that data were collected but twice a week and that the dates given for the first appearance of the insect in its various stages may be from one to three days later than the actual occurrence. Differences in latitude that are equivalent to less than half a day are not considered; those equivalent to more than half a day are counted as full days.

TABLE XL.—*Effect of differences in altitude and latitude on the time of appearance of spring-brood and first-brood codling moths and first-brood larvæ.*

Locality.	Year.	Date of emergence of first spring-brood moths.	Date of first larvæ collected under bands.	Date of emergence of first-brood moths.	Elevation above sea level.	Elevation above Charlottesville.
					<i>Feet.</i>	<i>Feet.</i>
Charlottesville, Va.	1912	May 7	June 6	June 20	400	.....
	1913	Apr. 18	June 5	June 14	400	.....
Greenwood, Va.	1912	May 8	June 6	June 23	900	500
	1913					.....
Hagerstown, Md.	1912	May 30	June 29	July 13	500	100
	1913	May 15	June 27	July 8	550	150
Winchester, Va.	1912	May 22	June 19	July 9	750	350
	1913	May 6	June 17	June 30	750	350
Fishersville, Va.	1912	May 18	June 11	July 2	1,500	1,100
	1913	May 3	June 14		1,500	1,100
French Creek, W. Va.	1912	May 13	June 24	July 20	1,600	1,200
	1913	May 6	July 5	July 23	1,600	1,200
Pickens, W. Va.	1912	June 13	July 31	Aug. 20	3,500	3,100
	1913	June 21				.....

TABLE XL.—*Effect of differences in altitude and latitude on the time of appearance of spring-brood and first-brood codling moths and first-brood larvæ—Continued.*

Locality.	Year.	Distance north of Charlottesville.		Number of days later than Char- lot- tes- ville accord- ing to law of latitude and altitude.	Actual number of days later than Charlottesville.		
		Degrees and minutes.	Miles.		First spring- brood moths.	First larvæ under bands.	First summer- brood moths.
Charlottesville, Va.....	1912	0					
	1913						
Greenwood, Va.....	1912	0 4	5	5	1	Same day	3
	1913						
Hagerstown, Md.....	1912	1 40	115	7	23	23	23
	1913			7	27	22	24
Winchester, Va.....	1912	1 10	80	8	15	13	19
	1913			8	18	12	16
Fishersville, Va.....	1912	0 4	5	11	11	5	12
	1913			11	15	9	
French Creek, W. Va.....	1912	0 50	60	15	6	18	30
	1913			15	18	30	39
Pickens, W. Va.....	1912	0 40	45	34	37	55	61
	1913			34	67		

RELATIVE NUMBERS OF LARVÆ ASCENDING AND DESCENDING THE TREES.

In 1911 several trees in a number of orchards were banded around the trunks and also around the bases of the larger branches. The lower bands were used to secure larvæ that had dropped with the infested fruit and ascended the trunk to spin up, and the upper bands were used for those that left the fruit before it dropped and descended toward the trunk for the same purpose. The following table shows the relative number of larvæ secured under the two sets of bands in the six orchards. In considering Table XLI due allowance should be made for an unknown number of larvæ that crawled across the bands or that spun up under the bark before reaching the bands.

TABLE XLI.—*Relative numbers of codling-moth larvæ collected from bands around the trunks and bases of branches, season of 1911.*

Locality.	Number of larvæ collected.			Per cent.	
	On trunk.	On branches.	Total.	On trunk.	On branches.
Hagerstown, Md.....	543	602	1,145	47.42	52.58
Smithsburg, Md.....	179	619	798	22.44	77.56
Hancock, Md.....	75	91	166	45.18	54.82
Fishersville, Va.....	96	68	164	58.54	41.46
French Creek, W. Va.....	146	96	242	60.33	39.67
Pickens, W. Va.....	29	30	59	49.15	50.85
Total.....	1,068	1,506	2,574	41.49	58.51

SEASONAL EFFECT OF WEATHER CONDITIONS ON THE DIFFERENT STAGES OF THE CODLING MOTH.

The beginning of emergence of the spring-brood codling moths varies greatly from season to season, depending in any given year upon the temperature conditions that prevail during March, April, and May.

It will be noted, however, that in spite of the wide variation in the time of emergence of the spring-brood moths in 1912 and 1913 there was a tendency for the later stages of the insect to appear at more nearly the same periods both years. This is probably due to an equalization of midsummer weather conditions subjecting the later stages of the insect to the influences of a more constant seasonal temperature factor. At Winchester, where the codling moth was under closer observation than at other points, we find that while spring-brood moths emerged at least 10 days later in 1912 than in 1913, the second-brood larvæ began entering the fruit at practically the same time both years.

Hammar,¹ in his report on the codling moth in Pennsylvania, gives the following in his general summary:

The time of the emergence of the spring brood of the moths is variable under different seasonal conditions and depends largely upon the relative lateness of the spring.

The time of emergence of the summer brood, or first brood, of moths is fairly constant and generally commences about the 1st of August.

From the results of the band records and rearing work of 1912 and 1913 it would seem, therefore, that in all except very unusual seasons we may expect the feeding of second-brood larvæ to begin in the different sections about as follows: Charlottesville, Va., July 1; Fishersville, Va., July 10; Winchester, Va., July 15; Hagerstown, Md., July 25.

CANNIBALISM AMONG CODLING-MOTH LARVÆ.

During the progress of these studies it was noticed frequently that when a collection of codling-moth larvæ was confined in a rearing jar a considerable loss in their numbers from cannibalism was likely to occur. This habit, of the stronger larvæ devouring their weaker fellows, has been commented on by Hammar.² He states that cannibalism among the larvæ probably takes place also under normal conditions. In the jars the loss from this cause during the present investigations was frequently sufficient to amount to a considerable factor in influencing the number of moths to appear later.

¹ Hammar, A. G. The codling moth in northwestern Pennsylvania. U. S. Dept. Agr., Bur. Ent., Bul. 80, Pt. VI, p. 111, 1910.

² Hammar, A. G. Life-history studies on the codling moth in Michigan. U. S. Dept. Agr., Bur. Ent., Bul. 115, Pt. I, p. 1-86, 1912. See p. 83.

NATURAL ENEMIES.

PREDACEOUS INSECTS.

It seems probable that many codling-moth larvæ, after leaving the fruit, are caught and destroyed by ants. A small red ant (*Solenopsis molesta* Say) was frequently met with on the bark of apple trees and under the bands engaged in killing and devouring the larvæ. Colonies of these ants that had their homes in the vicinity of banded trees seemed to form a habit of visiting the bands to obtain food. The collections of larvæ from trees in several localities were very considerably reduced in numbers from this cause. *Lasius niger* L. var. *americana* Emery, a species less abundant about the trees than the other, was also found killing the larvæ. These ants were determined by Prof. W. M. Wheeler.

Several species of beetles were found to be predatory on the larvæ and pupæ at the various stations. The most abundant of these was *Tenebroides corticalis* Melsh., both the larvæ and adults of which were frequently found under the bands devouring the larvæ and pupæ. Another beetle, *Hololepta lucida* Lec. (Pl. I, fig. 2), was found at Winchester with a codling-moth larva in its jaws. Two species of carabid beetles (*Calanthus opaculus* Lec. and *Platynus angustatus* Dej.) were common under the bands but were not observed to be feeding on the codling-moth larvæ. These beetles were determined by Mr. E. A. Schwarz, of the Bureau of Entomology. A coleopterous larva, which was determined as a species of *Telephorus* by Mr. H. S. Barber, was observed in the act of eating a codling-moth larva at Hancock in 1911.

HYMENOPTEROUS AND DIPTEROUS PARASITES.

Six species of hymenopterous parasites were reared from the codling-moth larvæ in the jars. Of these, *Ascogaster carpocapsæ* Vier. (Pl. I, fig. 1) was found at Winchester, Hagerstown, Smithsburg, Keyser, and French Creek, and outnumbered all others. An undetermined secondary parasite was found to be destroying this species in considerable numbers at Keyser in 1911. *Itoplectis marginatus* (Prov.) (fig. 23) occurred at Greenwood, Hagerstown, Winchester, and French Creek. A female of this species was observed on the trunk of an apple tree at French Creek ovipositing in a larva that had spun up under a scale of bark. *Macrocentrus* sp.¹ was reared at Greenwood in July, 1911; *Meteorus* sp.,² at French Creek in July, 1913; (*Microdus*) *Bassus*, n. sp. (Pl. I, fig. 4), at Smithsburg in July, 1911; and *Phanerotoma tibialis* Hald. at Charlottesville in 1911. The last species was determined by Mr. H. L. Viereck and the others by Mr. R. A. Cushman, of the Bureau of Entomology.

¹ Quaintance No. 7457.² Quaintance No. 7569.

A dipterous parasite, reared from codling-moth larvæ at Keyser in 1911, was determined by Mr. W. R. Walton, of the Bureau of Entomology, as (*Hypostena*) *Tachinophyto variabilis* Coq. (Pl. I, fig. 3). Only a few specimens of this species were obtained.

HAIRWORM PARASITES.³

Hairworm parasites of the codling moth (Pl. I, figs. 5, 6) were found at Greenwood, Keyser, and French Creek, being abundant in the second-brood larvæ at the latter place in 1911. These parasites were within the bodies of the codling-moth larvæ at the time collections



FIG. 23.—*Itoplectis marginatus*, a parasite of the codling moth. Enlarged. (Original.)

were made from the bands and usually issued from their hosts 10 days or 2 weeks after the larvæ were placed in the rearing jars. Occasionally dead larvæ, surrounded by a mass of dead hairworms, were found under the bands, and in a few cases the hairworms were found within apples borne by the banded trees. It was evident that infestation occurred at an early stage in the larval development and that all infested individuals died as full-grown larvæ. Most of the parasitized larvæ died within 10 days after being placed in the rearing jars.

The hairworms were from $2\frac{1}{2}$ to 5 inches in length, and three or four were frequently observed to inhabit one larva. In leaving the host they passed through the anal opening or broke through the

³ *Mermis* sp. Material was referred to Dr. B. H. Ransom, of the Bureau of Animal Industry, but as the specimens were all immature, they could not be determined specifically.

skin at some other point. After freeing themselves from the host, all that were observed writhed about actively for a few minutes and then died. Many of the hairworms did not escape from the codling-moth cocoons, but were found, at the time of the regular examinations of the jars, knotted together and dead, beside the flattened and shriveled larval remains. Table XLII shows the extent of parasitization at French Creek in 1911.

TABLE XLII.—*Extent of parasitization of codling-moth larvæ by hairworms at French Creek, W. Va., in 1911.*

Date larvæ were collected.	Number of larvæ collected.	Number of larvæ parasitized.	Per cent parasitized.
June 26.....	139	0	.....
July 3.....	68	0	.....
July 14.....	48	6	12.50
July 24.....	24	1	4.17
Aug. 4.....	14	3	21.43
Aug. 15.....	51	7	13.72
Aug. 23.....	34	11	32.35
Sept. 2.....	36	23	63.90
Sept. 13.....	43	21	48.84
Sept. 19.....	23	10	43.48
Oct. 3.....	22	6	27.27
Total.....	502	88	17.53

SUMMARY.

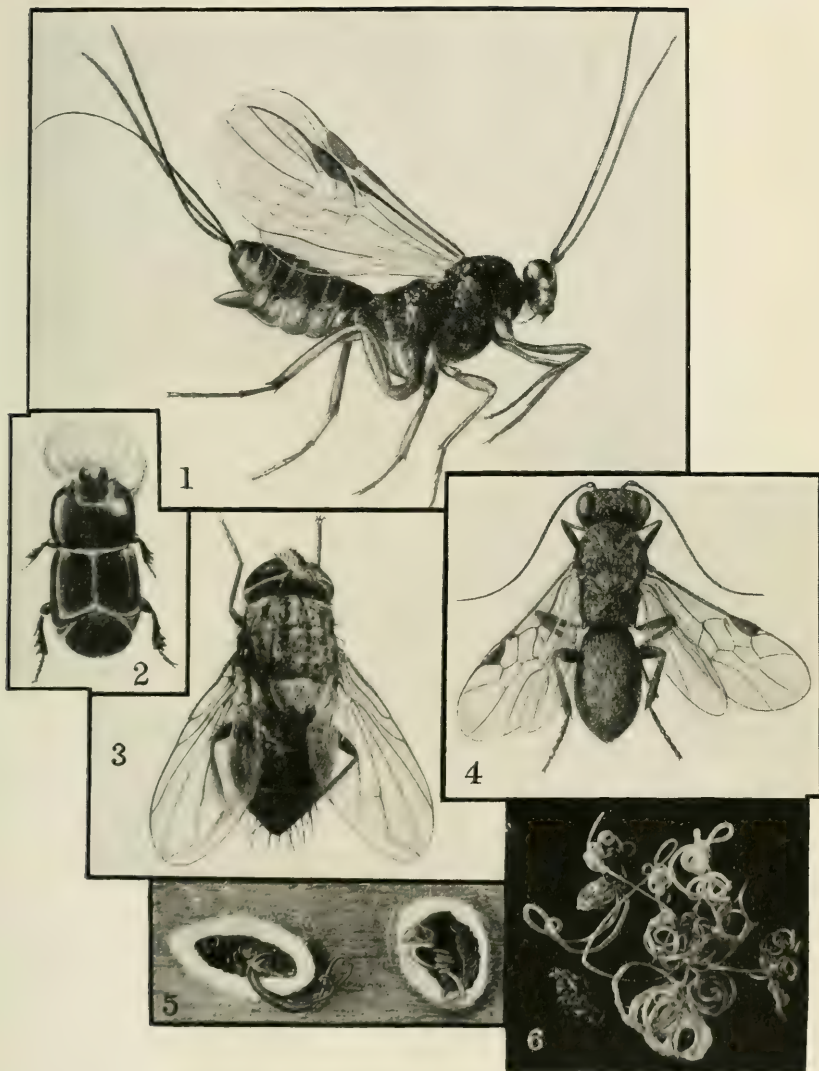
The foregoing account of the codling moth is based upon band-record studies conducted in 1911, 1912, and 1913 in several different localities of Virginia, West Virginia, and Maryland.

The stations at which the investigations were conducted comprise a difference in latitude of about 1° 40' and in altitude of about 3,100 feet. The most southerly and least elevated station was at Charlottesville, Va., the most northerly at Hagerstown, Md., and the one at highest elevation at Pickens, W. Va.

The chief features of the investigations consisted of banding suitable apple trees with strips of burlap, collecting at regular periods the larvæ that went beneath the bands to spin up, and rearing these larvæ in jars kept in the localities where the larvæ were collected. Examinations of the bands and rearing jars were made every week or ten days in 1911 and twice a week in 1912 and 1913. No detailed life-history studies were attempted.

During a single year the codling moth, in the region covered by the present studies, produces one full brood of larvæ and a partial second brood, the size of the second brood depending more or less on the latitude and altitude of the locality.

The studies show a marked difference in the time of appearance of the different broods in different localities. Charlottesville gave the earliest records for practically all broods and Pickens the latest.



NATURAL ENEMIES OF THE CODLING MOTH (*CARPOCAPSA POMONELLA*).

FIG. 1.—*Ascogaster carpocapsae*. FIG. 2.—*Hololepta lucida* devouring codling-moth larva.
FIG. 3.—(*Hypostena*) *Tachinophyto variabilis*. FIG. 4.—(*Microgaster*) *Bassus* n. sp. FIG. 5.—
Codling-moth larva killed in cocoons by hairworms (*Mermis* sp.). FIG. 6.—Mass of hair-
worms (*Mermis* sp.) taken from rearing jar, French Creek, W. Va. (Original.)

There seems, however, to be no constant rate of difference between the earlier and later localities. This seems to be largely due to the responsiveness of the species during its metamorphic changes to local and transient weather conditions.

During the time of the investigation the first-brood larvæ began entering the fruit at Charlottesville from April 28 to May 15, and second-brood larvæ from June 25 to July 1. At Pickens first-brood larvæ began entering the fruit from June 20 to July 1, and second-brood larvæ about August 10. Between these two localities there is a greater difference in the time of the regular periodical changes of the insect that occur late in the season than of those that occur early in the season. This is probably due to the cumulative retarding effect of the more frequent unfavorable weather conditions at the higher point.

For any given locality the variation in the time of appearance of spring broods in different years is greater than that of corresponding summer and fall broods of the same years.

Records of the numbers of larvæ collected from trees on which bands were placed around the trunks and also around the bases of the larger branches indicate that 41.49 per cent drop to the ground and then ascend the trunk to pupate and 58.51 per cent crawl down the branches from the infested fruit to pupate.

Where a collection of larvæ is confined in one jar there is apt to be a considerable loss due to cannibalism. It is probable that the weaker larvæ are sometimes devoured by their fellows under normal conditions.

Two specimens of ants (*Solenopsis molesta* Say and *Lasius niger* L. var. *americana* Emery) were found in several localities devouring codling-moth larvæ. Larvæ and adults of the beetle *Tenebroides corticalis* Melsh. were found frequently feeding on codling-moth larvæ and pupæ. Six species of hymenopterous and one of dipterous parasites were reared in the jars. Of these the most destructive to the codling moth were *Ascogaster carpocapsæ* Vier. and *Itoplectis marginatus* Prov. Hairworm parasites (*Mermis* sp.) were abundant in one locality and very materially reduced the number of wintering larvæ in the year 1911.

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BULLETIN No. 190

Contribution from the Office of Experiment Stations
A. C. TRUE, Director

Washington, D. C.



April 24, 1915

THE DRAINAGE OF IRRIGATED LAND

By

R. A. HART, Supervising Drainage Engineer

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INTRODUCTION.

It is now generally recognized that irrigated land may become waterlogged and impregnated with harmful mineral salts, and that drainage must be the means of the reclamation of land so affected. Already, in the United States, more than 10 per cent of the entire area that has been irrigated for any considerable period is either absolutely unproductive or is given over to the less valuable crops or to poor pastures; while even in the most recently developed irrigation projects serious injury is being wrought. These injured lands are to be found in all the arid and semiarid States and in practically every valley where irrigation is a factor in the agricultural development.

The feasibility of reclaiming these waterlogged and alkali lands has been demonstrated in numerous experiments, and methods have been developed by which the work can be done effectively and economically. It is the purpose of this bulletin to present in concise form the fundamental principles upon which the reclamation of such land is based, to describe typical conditions and the best methods of treating them, and to give practical advice as to actual operations.

NOTE.—The information in this bulletin is intended for drainage engineers and landowners of the arid West. It is not applicable to the humid section of the United States.

Drainage practice in the arid section differs greatly from that in the humid region. The nature of the land requiring drainage is different, and the methods applied are unlike those employed in the humid section. In fact, there is little in common between the two situations, and drainage experience in the humid section avails little in dealing with the problems of draining irrigated lands. For this reason literature on the general subject of drainage should be used with caution, as the difference in conditions between the arid and humid regions has been clearly recognized only within the last few years.

MANIFESTATIONS OF POOR DRAINAGE CONDITIONS.

Injury wrought by overirrigation manifests itself in several ways. In some cases the lands are literally swamped, and ponds, bogs, and tule marshes are dominant features. In others the ground is merely waterlogged, and the injury is shown by the wet condition of the soil, by the presence of alkali salt crusts on the surface of the higher spots of ground, and by any vegetation that may have survived the inhibitive conditions. Very often, however, there is no visible sign of wetness, and the only marks of the injury are the incrustations of alkali salts, the presence of highly alkali-resistant plants, or the absence of all vegetation in the worst-affected areas.

SPECIFIC OBJECTS OF DRAINING.

It is important, at the outset, to understand the specific results which it is proposed to accomplish by draining. These may briefly be stated as follows: (1) To lower the ground-water table to such a depth that the moisture and air conditions within the root zone are properly balanced; (2) to provide an outlet for percolating water, so that fluctuations of the ground-water table within the root zone will be prevented; (3) to effect rapid removal of the excess moisture resulting from spring thaws; and (4) to provide an outlet for the downward-moving water used to dissolve out the injurious salts.

PRELIMINARY INVESTIGATIONS.

NECESSITY FOR KNOWLEDGE OF CONDITIONS.

Having in mind the above-mentioned objects of draining, it is clear that the existing conditions must be known before work is commenced, and that the system must conform to these conditions. Random procedure is manifestly poor policy where the objects aimed at are so definite. A little study and the application of judgment will often indicate how the drainage may be satisfactorily accomplished at comparatively small cost. On the other hand, it is quite possible, in the irrigated section, to install a system having many more lines than are necessary, and still meet with total failure. There are few projects so small and apparently so simple as not to warrant the

employment of one trained in this work to make the preliminary studies and to design the system. From a drainage standpoint, the average landowner rarely has any extensive knowledge of the conditions on his farm, especially of those beyond the plow depth, which latter are, in this form of reclamation, of the highest importance.

SOURCE AND AMOUNT OF DAMAGING WATER.

The most important factors affecting the design of a system of drainage for irrigated land are the source and movement of the damaging water. The water does not come directly from precipitation, as is the case in humid regions, although precipitation may have a bearing on the problem and may need to be considered. Percolating irrigation water usually is the cause of the injury, and this may have its movement *downward* through the soil of the tract being irrigated, *laterally* through pervious strata extending back under higher lands, or *upward* from pervious strata having considerable depth and connecting with distant sources at a higher elevation. Under the latter conditions the water is under pressure. The water may represent waste from the irrigation of the injured tract itself, adjacent lands, or distant lands; again, it may represent direct loss from irrigation ditches, laterals, canals, and reservoirs. In any case, a successful drainage system can not be designed until the source of the damaging water is known, and until the movement of the underground water has been studied.

The most difficult problem in connection with the drainage of irrigated lands is the determination of the quantity of water that will be developed and for which it will be necessary to provide an outlet. For tracts up to a few hundred acres in area and having average soil and subsoil, the simplest method, and one which has proved reliable, is to determine the irrigation supply and to provide a drainage capacity of one-third that amount of water. As the size of the tract increases, however, this coefficient should be decreased. If the subsoil be clay, provision for one-fifth the irrigation supply will suffice for small tracts. In areas of a square mile or more, it is usually sufficient to provide for a run-off of from $1\frac{1}{4}$ to $2\frac{1}{2}$ cubic feet per second for each square mile, depending upon the porosity of the soil and the duty of the irrigation water.

The foregoing bases do not apply to the drainage of lands underlain by gravel. In such lands it is the area that is contributing the damaging water, not the area to be drained, that must be taken into consideration. Oftentimes the drainage discharge from gravelly lands is several times greater than the irrigation supply of the injured tract.

If the height of the ground-water table be variable, it is possible to make a close estimate of the necessary capacity by ascertaining

the average *dangerous* rise throughout the season and the approximate percentage of void spaces in the soil. From these data the daily run-off that must be provided for may be computed.

Another method of determining the required capacity is to ascertain the maximum height of the water table above the required drainage depth, and to determine the approximate percentage of void spaces in the soil. Then, assuming the number of days in which it is required to remove the calculated volume of water, the daily run-off may be determined. If the ground water be always at the surface, the same system may be employed, but the evaporation and any surface run-off that occurs must be taken into consideration.

TOPOGRAPHY AND SOIL.

The required capacity of a drainage system can not be reliably determined without an accurate survey and a careful study of the soil and subsoil. The survey should be made to ascertain the amounts and directions of slope, the locations of natural and artificial features that may influence the design of the system, and the dimensions of the tract as a whole and as to its various classified portions. The subsurface examinations should yield information as to the nature of the soil, its stratification, its water-carrying capacity, and its capillary power.

From the data thus obtained, the proper location, frequency, and depth of drains may be determined, after which the sizes of the various units may be ascertained by reference to the required capacity.

OPEN CANALS.

In the design of an open canal the important points to be considered are the effectiveness of the drain, its carrying capacity, its mechanical construction, and its maintenance in good condition.

Experience has taught the necessity of providing considerable depth. This should never be less than 6 feet, presuming that the maximum depth of flow will be 1 foot, and 8 feet would be a better minimum. Thus, as is shown in figure 1, the cross section of stream flow is small as compared with the cross section of the canal itself. The side slopes are quite flat; they never should be steeper than 1 horizontal to 1 vertical, and it is sometimes necessary to make them as flat as 3 horizontal to 1 vertical.

A berm of not less than 6 feet should be left on either side of the canal and the spoil should be banked up on one or both sides. The spoil should not be scattered over the adjacent farms for a number of years, at least, as it is "dead" material and will do injury to the soil. The spoil banks are useful in keeping waste water and storm water from entering the drain directly and injuring the channel. All of the spoil may be placed on one side if it is desired that a roadway run parallel with the drain.

The size of drain required depends upon the amount of water to be carried, the slope of the canal, the condition of the channel, and the shape of the cross section of the flowing water. All of these factors influence the velocity of flow, which should be low enough to prevent erosion and yet high enough to prevent silting and the growth of vegetation. The desired velocity controls, to a large extent, the values that should be given the foregoing factors. Average soils will stand a velocity of 3 feet per second, and a velocity of 2 feet per second will prevent the growth of vegetation and the deposition of silt. The slopes required to give these velocities vary from one-half foot per mile in very large canals to a number of feet per mile in the case of small laterals. In general, if the ratio of the depth of flow to the cross section of flow be small, greater slope will be necessary or permissible.

Laterals or farm drains of just the right capacity to care for the water would be too small for economical construction. Furthermore,

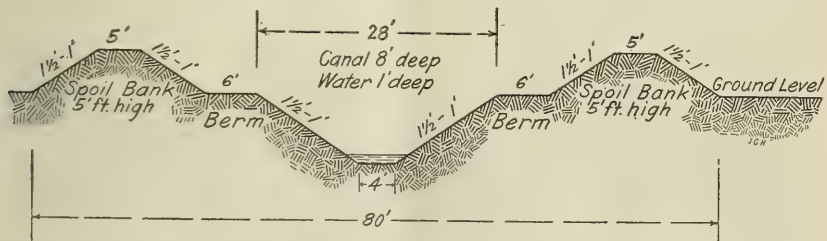


FIG. 1.—Ideal cross section of open canal in medium soils, showing relation between sectional areas of stream and canal.

a small amount of material falling into such drains would seriously obstruct them. It is therefore considered good practice to give open ditches a minimum bottom width of 4 feet, except in very stiff, homogeneous clay, where it may be 3 feet.

COVERED DRAINS.

LUMBER BOX DRAINS.

Lumber box drains are chiefly employed in isolated places where transportation rates are so high as to make the cost of tile prohibitive; their greatest advantage is, perhaps, their cheapness. This advantage disappears, however, in localities near tile factories. Another advantage of such conduits is that the boxes may be laid in comparatively long sections, which afford a more stable bearing and make for a more uniform channel. The life of such a conduit is reasonably long if the lumber is always wet, but where alternate wetting and drying take place the material may fail in a few years. The presence of alkali salts seems to be beneficial rather than injurious to the wood, but sodium sulphate destroys the nails in a very short time. It is necessary, therefore, so to construct the boxes that their integrity of form

does not depend upon the nailing. Under ordinary conditions the soil becomes compacted within a few months after installation, so that the boxes hold together, although the nails may have been eaten entirely away. Boxes are less liable to displacement than are tile, but if the ground is very mushy it is difficult to lay the former before caving takes place. Boxes are also the more likely to be buoyed upward by the fluid soil, but on the other hand it is often necessary to lay planks under tile to maintain grade and line, a precaution which is unnecessary in the case of boxes. On the whole, however, it may be said that lumber boxes should not be used where tile is available at a comparable price.

In no case should a triangular or V-shaped box, or an open-bottom box be employed.

The simplest form of lumber box drain is shown in figure 2, *a*. The lumber runs the long way of the box and the sections may be as long as 16 feet if the soil conditions warrant. If the ground tends to cave,

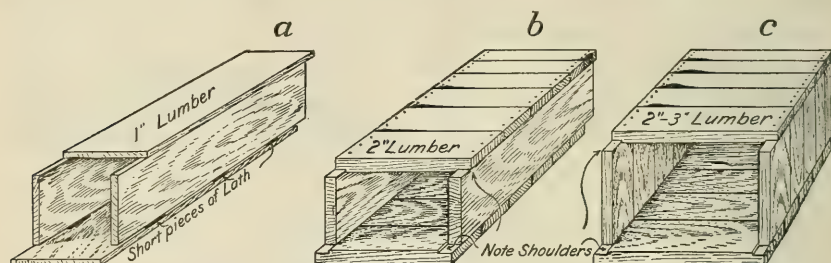


FIG. 2.—Types of lumber box drains.

shorter sections should be employed. The top is nailed tightly to the sides, but the bottom is separated from the sides by short pieces of lath placed at intervals of 2 or 3 feet. The slit thus left provides for the entrance of the water. In soft ground the slit should be protected against the entrance of silt and sand by a gravel or cinder filter. One-inch lumber may be used for boxes up to 8 inches in width, and 2-inch lumber for boxes up to 12 inches in width. For somewhat larger boxes the lumber should run crosswise, as shown in figure 2, *b*. It is a convenient arrangement to employ 2 by 12 inch planks for the sides and to have the top and bottom pieces cut to the proper length. These should be milled, as shown, to afford shoulders which will hold the box together after the nails are destroyed. One-inch material may be used for the bottoms, except in soils so fluid that an upward pressure is exerted. The top pieces should fit tightly together but the bottom pieces should be separated from one-fourth to one-half inch to provide for the entrance of the water. Such boxes should not be over 24 inches in width.

For still larger sizes, 3-inch material should be used and the side planks should be wider. It is not advisable to use lumber over 16

inches in width, however, nor to make the sides from two widths cleated together. For the larger sized box drains, it is best to build the box in short sections as shown in figure 2, *c*. This type of conduit is especially useful in bad ground, as it may be laid in much the same manner as tile. The lumber should be milled to provide shoulders. The sections should interlock, as shown in figure 2, *c*. These shoulders may be easily and cheaply cut by passing each end of the top and bottom pieces over a circular saw, the latter being so set as to cut out a rabbet as deep as the thickness of the saw and as wide as the thickness of the side planks.

CEMENT TILE.

The use of cement tile has occasioned much discussion, owing to the failure of lean, improperly-made tile. However, even the best of cement tile is open to suspicion where sodium or magnesium sulphates are present in the soil. Cement tile should be made very rich, usually not leaner than 1:2:4; the materials should be well gauged, mixed very wet, and carefully tamped into form, after which the tile must be properly cured, preferably by steam. These requirements absolutely eliminate hand-tamped tile made so dry that they may be taken from the forms at once.

CLAY TILE.

Clay tile, when properly made of suitable materials, are very durable and may be depended upon, however strongly alkaline the drain water may be. They should be vitrified and as impervious as possible; the walls should be smooth and of fairly uniform thickness; the bore should be cylindrical and the ends smooth. There should be no serious cracks or blisters, and the content of foreign material should be small. Lime, especially, should be avoided. The tiles usually come in lengths of either 1 or 2 feet in the smaller sizes, and 3 feet in the larger sizes. Under ordinary circumstances the 2-foot length is preferable for the smaller sizes, as tiles of this length are more easily handled and keep their positions better, while sufficient inlet area is afforded by the 2-foot spacing of joints. The walls should be sufficiently thick to give the tile the strength necessary to withstand the pressure of the saturated earth.

SIZE OF CONDUIT.

The carrying capacity of a tile drain depends upon the diameter of the tile, the slope of the drain, the accuracy with which the tiles are laid and the smoothness of their inner walls, and the general plan of the system as regards turns, changes in slope, manholes, etc. The carrying capacity of a box drain depends upon the above-named factors and upon the shape of the box, the most advantageous shape, so far as capacity is concerned, being that in which the width is twice the depth of flow. The velocity should be high enough to prevent

silting, and the higher the velocity the smaller the cross-sectional area necessary to provide for a given discharge. The velocity is usually limited by the available fall, however, and it is quite the general thing, in the irrigated section, to have the drains run across the greatest slope, rather than with it. The smaller-sized tile should have a fall of at least 1 foot per thousand feet, and the larger sizes at least one-half foot per thousand feet.

Tile having an inside diameter of less than 4 inches should not be used, and even 4-inch tile should be used sparingly, usually at the extremities of small branches. Experience has shown that the use of tile less than 5 inches in diameter is not warranted by the comparative results and cost. The cost of trenching and laying is about the same for 4-inch as for 6-inch tile, while the latter has about three times the carrying capacity of the former. The 6-inch tile also presents a much larger surface to the surrounding soil and has more than double the area of bore, so that a given amount of silting represents a much less obstruction to the flow; also it is much easier to insert devices for clearing out the 6-inch line than is the case with the 4-inch one.

CHOICE OF TYPE OF DRAIN.

Both the open canal and the covered conduit are applicable to the drainage of irrigated lands. Each serves a purpose and under certain circumstances there is no question as to which to employ. There is, however, a zone in the scale of varying conditions in which the choice is not easily made. These conditions are worthy of special consideration.

The primary purpose of open canals is for main outlet systems or large laterals in which provision must be made for a considerable flow. Covered drains are for farm drainage proper. There are few reasons, save that of economy, why covered drains should not be used throughout, as they are more desirable in most respects; and when the problem as to which type to select arises, the question of desirability should be considered with that of economy. Open drains are unsightly and harbor obnoxious weeds; they occupy valuable space and often cut the land into inconvenient shapes, increasing the difficulties of cultivation and irrigation. Bridges, culverts, and flumes must be provided, and a constant watch must be kept lest irrigation streams find their way into the canals and do great damage to both the canals and adjacent lands, as well as waste the water. The maintenance cost of open canals is usually high in the irrigated sections, owing to the nature of the soil and to other causes.

The covered conduit usually requires no right of way and occupies no valuable land. If properly designed and laid it requires very

little maintenance. There is little danger of irrigation water getting into the drains, and the only way in which vegetation may do damage is by the entrance of water roots from certain trees and plants. This trouble may be avoided by keeping such trees as willows, cottonwoods, tamaracks, etc., well away from the drain lines, and by cutting away a narrow swath of such plants as the sugar beet from directly over the tile line. Black willows will send out roots to a distance of 200 feet and choke a drain, while sugar beets planted directly over a line will reach and obstruct a drain 5 feet deep. These roots penetrate only the disturbed soil of the trench, however, so it is necessary to remove but a narrow swath.

In deciding whether a large covered drain or an open canal shall be employed, it is necessary to calculate the original cost of each, taking account of all auxiliary and protective devices required, and then to add to each sum an amount large enough to give an annual return, at current rates, sufficient to cover the cost of maintenance. The consideration of the first cost alone gives very misleading results, as it has often been found that the difference in the cost of a very few years' maintenance would have more than paid the difference in first cost between the two types of drains. Thus, if a covered drainage system costs \$1 per foot to construct, and the annual maintenance is 1 per cent of the first cost, 20 cents per foot must be added to yield an annual income of 1 cent per foot at 5 per cent interest, which makes the total cost \$1.20 per foot. An open drain having the same capacity will cost about 30 cents per foot for excavation, 25 cents per foot for right of way, and 10 cents per foot for inlets, flumes, bridges, culverts, fences, etc. If the annual maintenance be taken at 10 per cent of the excavation cost, which is reasonable, 60 cents per foot must be added to yield an income of 3 cents per foot at 5 per cent, which gives a total of \$1.25 per foot. The covered drain is to be preferred, therefore, even from the standpoint of actual cost; and when the other factors are considered there is no room for comparison between the two types.

Practice in the humid section is leaning more and more toward the covered drain, and tile having an inside diameter of 3 feet are not uncommon, while still larger sizes are sometimes employed. Until quite recently, very little tile over 12 inches in diameter had been used in the arid section. However, conservative estimates based on present prices and conditions show that it would be economical to use 20-inch tile, rather than the open canal of the same capacity; while improvement of methods, increase of land and crop values, and the decrease in the cost of materials that are now being witnessed, make it seem reasonable to predict that very shortly the eastern standards of practice will be adopted.

LOCATION OF OPEN CANALS.

In considering the question of location, the specific purpose of the drain must be kept in mind. Outlet systems require treatment different from that given small canals or ditches intended to accomplish farm drainage directly. The former must usually follow the natural depressions and watercourses, while the latter must be located with strict regard to the source of the damaging water, as is the case with tile drains. For this reason the discussion of location of covered drains (pp. 18-24) may be understood to refer to the location of open farm drains as well.

It is generally a feasible and satisfactory practice to have small, open ditch outlet drains and laterals extend along the highways, as the roadway is thus drained and less right of way is required, since the spoil may be thrown into the roadway and crowned, making an excellent thoroughfare where roads may ordinarily be impassable during wet seasons. Figure 3 shows how this arrangement may be

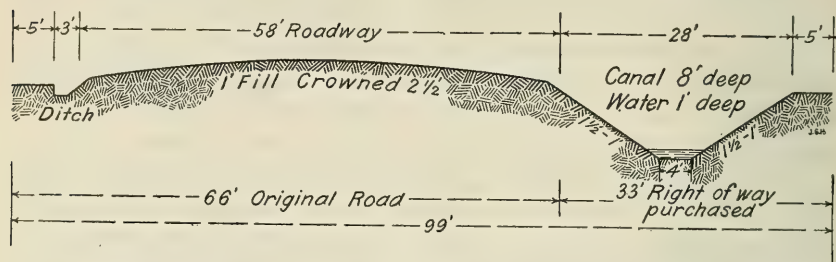


FIG. 3.—Illustrating how a canal may be built along a 4-rod road by purchasing a 2-rod right of way and placing all the spoil on the road.

effected, in the case of a 4-rod road, by the acquisition of a right of way 33 feet in width. A walk 5 feet in width is provided on either side, the drainage canal has the necessary depth and a desirable cross section, a small surface drain is provided at the left side of the road, and a roadway is afforded which is 58 feet in width and has a crowned surface rising $3\frac{1}{2}$ feet above the general ground surface.

DEPTH AND LOCATION OF COVERED DRAINS.

One of the most important questions in drainage practice in the irrigated section is the proper depth at which to lay drains. Water often rises in soils, by capillary attraction, to a height of several feet above the free water level, and the presence of salts in solution increases the height of the rise and the rapidity of the movement. Evaporation takes place, and as a result the salt solution is concentrated at the upper limit of saturation. The height to which capillary water will rise depends upon the type of the soil, the wetness, the amount of foreign material in the soil, the amount of salts in the water, and the temperature. The rise may vary from a few inches

in gravel to a number of feet in fine, silty sand, or clay, soils; the rise may even extend to many feet in special soils containing a high percentage of gypsum or of calcium chlorid. Average soils show a range of from $1\frac{1}{2}$ to 4 feet.

Plants in the arid region are unusually deep rooted, and they can not thrive unless the air and moisture conditions are properly balanced. Therefore, the plane of supersaturation must be kept below the root zone, and since this plane is several feet above the free water level it is necessary to give drains a considerable depth.

The presence of alkali salts complicates the problem of depth, for not only is the capillary rise of the water thus increased and expedited, but it is essential that the injurious salts themselves be kept down. It is highly important that a downward movement of the water in the root zone be maintained to offset the natural upward movement due to capillary attraction and evaporation. Owing to the presence of animal and worm burrows, cracks, root spaces, and other noncapillary openings, a great deal of water moves downward without coming into contact with salts; but the upward capillary movement is entirely through the capillary pores where the salts are confined. The natural tendency, therefore, is for the salts to move upward rather than downward. Drains should never be less than 5 feet deep, and experience has shown that depths of from 6 feet to 8 feet are much more efficient. The optimum depth for drains is that which will prevent fluctuations of the ground-water level within the root zone, and yet will keep capillary water within reach of the plant roots.

In determining proper depths the location of any stratum which is either more or less pervious than the adjacent soil is of great importance. This involves a careful study of the structure of the soil for considerable depths. It is quite possible to construct a well-arranged system of considerable depth which will be absolutely ineffective but which would have been highly effective if the depth had been increased less than 1 foot. Figure 4, a, illustrates an actual case of this kind. This system would have been successful if the tile had been laid as is indicated in b. The porous stratum carries water from higher lands, and where the stratum pinches out the water is forced to the surface, forming a bog. In the system as constructed, the tile was laid above the water-bearing stratum, in dry material, and the water continued to pass under it. Had the system been laid a foot deeper the stratum would have been cut and the flow intercepted.

Figure 5 shows a case where a tile line has been laid 5 feet deep in a soil underlain by a stiff, impervious clay at a depth of 6 feet. Here again the water passes under the drain and the system is a failure, though it could be made successful merely by deepening the drain.

In general, it may be said that the proper location of a drain depends upon the surface and subsurface topography, the nature of the soil, and the source of the damaging water. Subsurface conditions have more to do with the location of drains than does the sur-

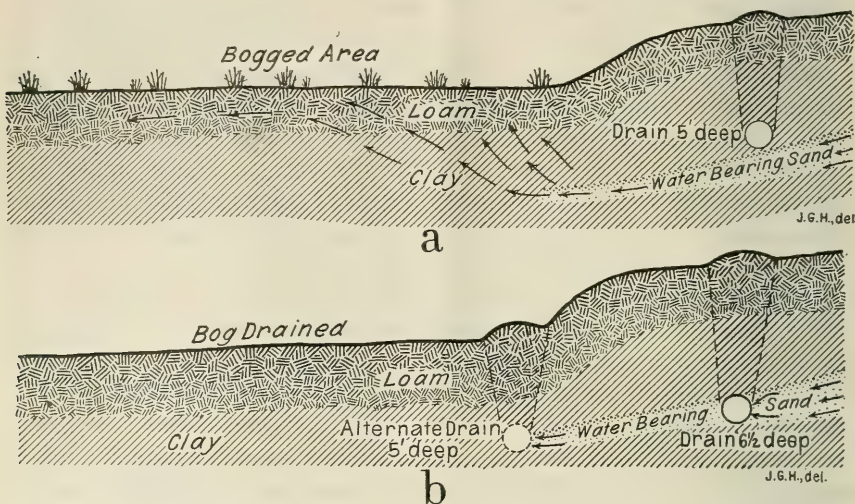


FIG. 4.—Illustrating importance of proper depth of tile: a, Drain ineffective owing to insufficient depth. The water passes through sand stratum under the tile, which is in dry clay. b, Two ways of making above system effective—by deepening drain 1 foot, or by changing the location so that line will cut through previous substratum, the depth remaining the same.

face topography, but most important of all is the source of the damaging water, since in many cases it is necessary to intercept this flow at the point of entrance to the tract. The question of location,

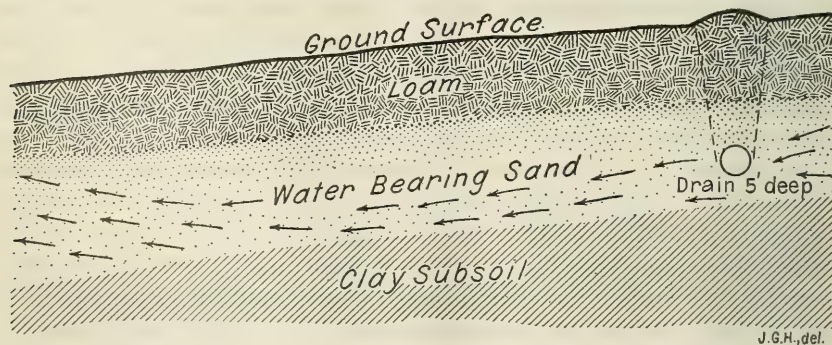


FIG. 5.—Section of water-logged tract in which attempt at drainage was unsuccessful owing to insufficient depth of drain. The trench should have been cut entirely through the water-bearing sand and the tile laid on the underlying clay.

however, must often be considered in connection with that of required depth. For instance, referring again to figure 4, b, it will readily be seen that a drain located at the change of slope will be fully as effective and more economical than one located on the top of the rise.

No general rules can be given as to the arrangement of drains on an irrigated tract. The proper locations have been predetermined by nature and it is necessary to study the conditions well in order to avoid mistakes. However, since the damaging water in the irrigated section moves underground, it is the subsurface rather than the surface conditions that must be studied. Few of the lines will be parallel, but economical features of design must often be sacrificed to an arrangement that will give the best drainage results.

PROTECTIVE DEVICES FOR OPEN CANALS.

Changes in the direction of a canal should be made by easy curves; otherwise one bank will be cut away while silt will be deposited at

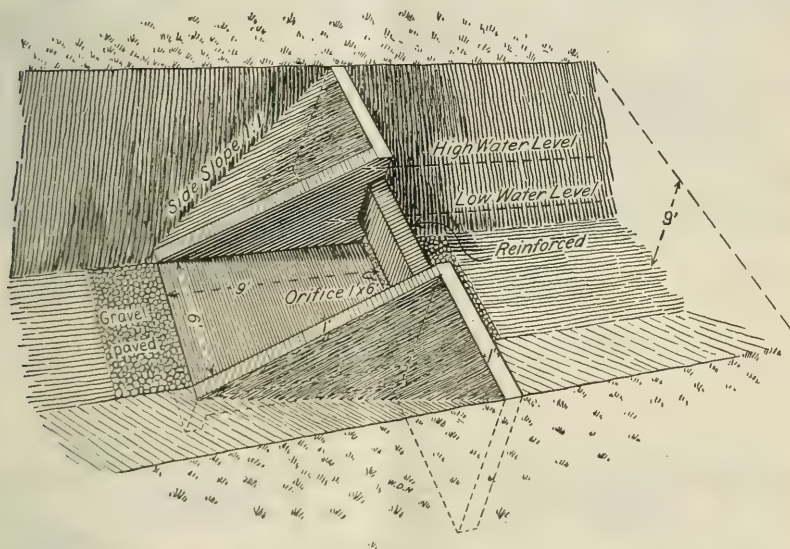


FIG. 6.—Concrete automatic regulating check for preventing erosion during periods of heavy discharge.

the opposite side of the channel. If a section of canal having a slope which causes erosion discharge into a section having less slope, silt will be deposited in the latter, due to the reduction in velocity, and the channel will become obstructed. Where the slope of a canal is such that the velocity will cause erosion, "drops" should be installed to lower the water from one level to another without injury to the channel.

CHECKS.

In some canals the usual flow is not sufficient to cause damage by erosion, but occasional floods increase the discharge to such an extent that the velocity is destructive. In such canals checks, designed to operate as spillways during high water but having an opening at the level of the canal bottom of sufficient size to pass the ordinary flow,

should be installed. Figure 6 illustrates such an automatic regulating check for use in a channel having a normal capacity of 8 second-feet,

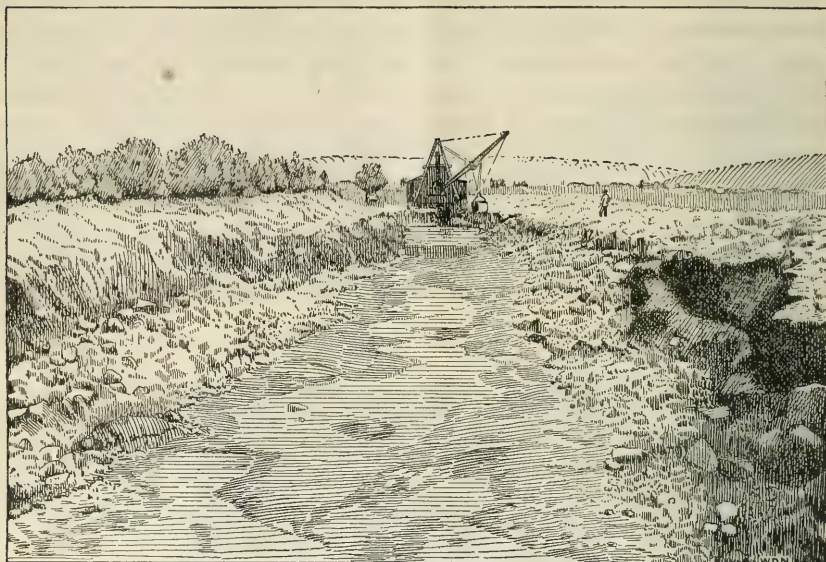
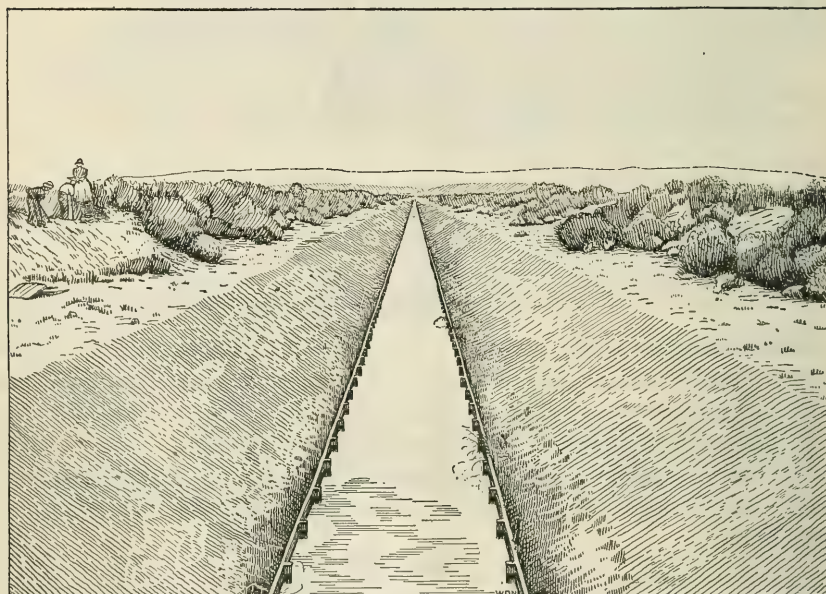
*a**b*

FIG. 7.—A canal in semifluid soil: *a*, before cunetting; *b*, after cunetting.

which will handle a discharge of 240 second-feet without danger of erosion.

CUNETTES.

If the soil be semifluid, so that the banks will not stand, it is necessary to install a cunette. This is done by driving timber piles at intervals of a few feet along both edges of the proposed bottom of the canal, and building in a plank waterway between the piles. Such a cunette supports the canal banks admirably. Figure 7 shows a canal in a semifluid soil, before and after cunetting.

ENTRANCE OF LATERAL DRAINS.

Lateral drains should be so located that at their outlets the water they discharge will be flowing in nearly the same direction as that in the main ditch. Grades of laterals should be adjusted to that of the main so as to prevent erosion. If the fall is so great that sufficiently flat grades can not be secured, drops should be installed. At points where waste water from irrigation enters the ditch, flumes or drops should be constructed to prevent the water from damaging the sides of the ditch and filling the channel with eroded material.

FLUMES AND BRIDGES.

Irrigation canals and ditches should be carried across drains in carefully constructed flumes or pipe lines of ample capacity, or, if their elevations are about the same, one stream must be siphoned under the other. Properly constructed bridges should be provided wherever crossings are necessary, as culverts are usually not satisfactory. At least 2 feet of clearance should be left between the surface of the water and the stringers of a bridge, so that floating weeds or other débris will not be caught and cause obstruction. No diversion dams or similar obstructions should be permitted in the channel.

PROTECTIVE DEVICES FOR COVERED DRAINS.

MANHOLES.

A change in direction of a line of tile should be made gradually by a smooth curve, or a manhole should be installed at the point of change. If the soil contains much fine sand, a combination manhole and sand trap should be located at such a point, as well as at every change from a steep to a lighter grade. Such a device serves as an observation well in which the flow may be seen and the general conditions of the system watched. It also serves as a settling basin for any sand or silt that may be carried by the drain, and if the trap is made to extend a foot or two below the drain, a chamber is formed in which a considerable amount of sediment is held until an opportunity is afforded for its removal. The manhole may also be provided with a surface inlet to enable the drain to take care of surface water, and, if desired, to provide for flushing the drain. As a manhole proper it provides a means for the operation of a root-cutting or drain-

cleaning device, operated by sewer rods. If it is expected that such work will be necessary the drains should be laid out in straight lines, with grades as uniform as possible; and a manhole should be provided at each junction, change in direction, change in slope from a steep to a lighter grade, and on straight sections at intervals not exceeding 500 feet.

On straight lines a manhole may be made long and narrow, but at a junction or turn it should be made square to facilitate the operation

of rods and to prevent the sediment from being carried across the trap. A convenient size is 4 feet square. In constructing the manhole, brick or concrete is preferable, but lumber is often employed. When built of lumber, 2-inch material should be used. Figure 8 shows a simple type of manhole, constructed of lumber and so designed that earth pressure will maintain it in spite of the failure of the nails. Figure 18, page 23, illustrates the application of manholes. In most places the manhole should be provided with a bottom and it should

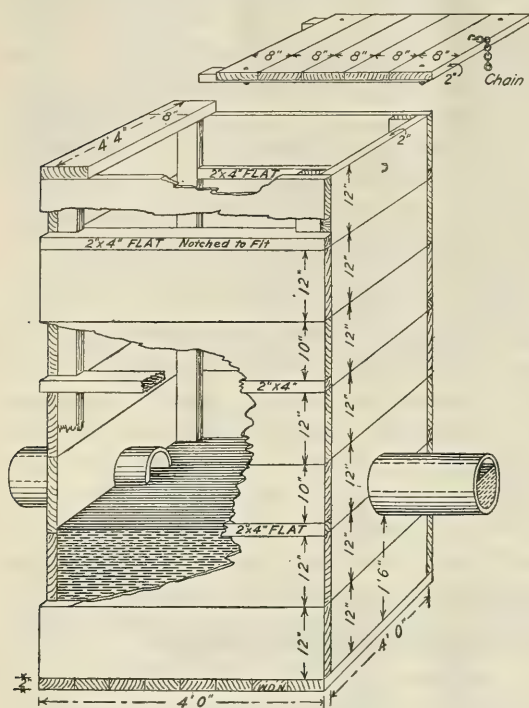


FIG. 8.—Combination manhole and sand trap with cover (Miller design), that does not depend upon nails to hold it together.

always be fitted with a cover that may be locked down.

OBSERVATION WELLS.

If little sand be present, rendering sand traps unnecessary, it is still desirable that opportunity be afforded for observation of the flow at various points throughout the system. Nothing serves this purpose better than a vertical stack of large-sized tile, extending from a little above the surface of the ground to a foot or more below the tile line, and having holes cut in the lower length to accommodate the drain. Such a device is shown in figure 9. As may be seen, a small settling space is provided from which sediment may be removed from time to time by means of a telephone spoon. A cover should

always be provided. This device costs little and occupies but small space. If desired, the top section may be removed at any time, a cap provided, and cultivation carried on directly over the top. Such a device may also be installed between regular manholes, for inspection purposes. Figure 17, page 22, illustrates the application of observation wells.

SURFACE INLETS AND FLUSHING WELLS.

A vertical stack of tile is also useful as a surface inlet and flushing well. Figure 10 shows how it should be installed. The bottom

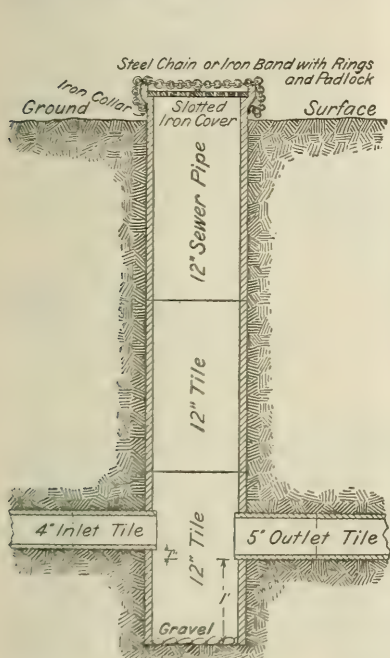


FIG. 9.—Observation well and sand trap constructed of tile.

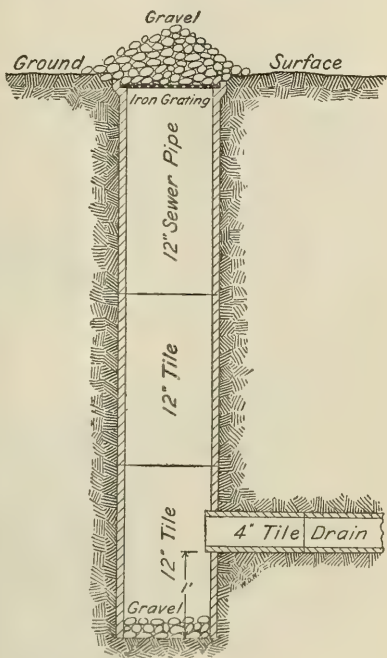


FIG. 10.—Standpipe, built of tile, for flushing drain or to act as surface inlet.

should be paved with coarse gravel and the top provided with an iron grating and a mound of gravel or crushed stone. Such an inlet should be installed wherever a drain crosses a depression or flat, so that the waste water or storm water may not pond for a sufficient length of time to puddle the soil or "burn" the crop. One of these should also be placed at the upper end of each branch line as is indicated in figure 17, page 22.

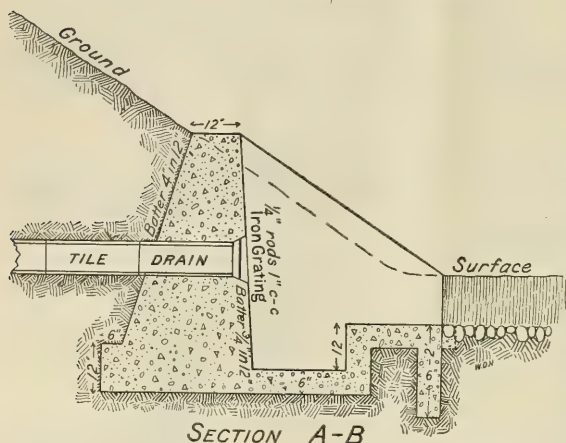
FLUMES.

Flumes should be provided for all canals and ditches that cross underdrains, and care should be taken to prevent large quantities of water from flowing across these drains, particularly during the first two seasons after the installation of the latter.

BULKHEADS.

A bulkhead should be constructed at the outlet of the underdrainage system to avoid injury from frost and caving of the banks at that point. This may be made of concrete, brick, or timber. Care should be taken that it has a good foundation, in order that it may not be undermined.

Figure 11 shows a concrete bulkhead which may be easily and cheaply installed and which will give satisfactory service. A network of wires or small rods of copper or iron should be placed across the outlet to keep out small animals.



SOME TYPICAL PROBLEMS AND THEIR TREATMENT.

INTERCEPTION OF LATERAL SEEPAGE.

Figure 12 is a map and cross section of a typical case of water-logging due to seepage from higher lands, to which the interception method of drainage should be applied. The damaging water is conducted through a pervious stratum that lies at a moderate depth, and owing to a change in slope from a steep to a lighter grade

this water is forced to the surface.¹ The drain should be located at the change in slope, as shown, and should be run diagonally across

¹ The slopes of the land are indicated by lines drawn across the map, any one of which lines passes through points of the same elevation, this elevation being that shown on the line. These are called contour lines. The lines shown on the map are at 1-foot vertical intervals, and may be compared with the successive shore lines of a pond of water which is rising or falling 1 foot at a time. It is plain that the degree of slope of the land is indicated by the frequency of the contour lines, the latter being close together on steep land and spread apart on land of slight slope.

the slope and connected with an outlet drain. One of the commonest locations of seeped lands is this belt of comparatively level land at the foot of a steeper portion, and there is no place where drainage may be more economically applied. A single drain line will usually intercept the flow from outside sources, and the pervious stratum, being relieved of its water, serves as a drainage system to take care of the water applied to the tract itself. The pervious stratum may well be considered a great sheet drain.

INTERCEPTION OF VERTICAL SEEPAGE.

A special case, involving the same principles as the one just mentioned but introducing a peculiar condition and a unique method of solution, is shown in cross section in figure 13. No map

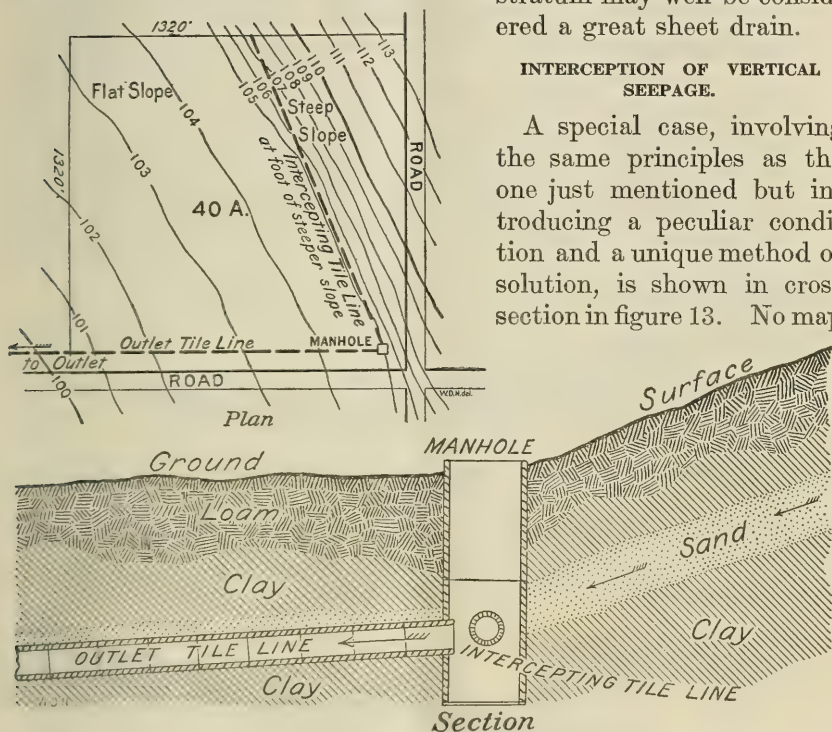


FIG. 12.—Plan and section showing typical case of water-logging due to seepage from higher land.

is given, as the surface topography is similar to that shown in figure 12, and the drains have the same location and depth. The water moves down the slope from higher lands through a very deep pervious stratum. At the change of slope the pressure forces the water to the surface. Owing to the considerable depth from which the water must rise, it is spread over a large area and there is little in the appearance of the ground surface to indicate its source. The condition may be relieved by a single drain, located as shown in figure 12, and connected by means of relief wells to the pervious substratum. The water rises in the relief wells, owing to its pressure, and flows out of the drains. This situation is not infrequently met with, and until subsurface conditions are thoroughly explored the problem appears baffling.

Ordinarily, a satisfactory relief well may be bored with an 8-inch post-hole auger. It should be cased with tile or pipe, or filled with

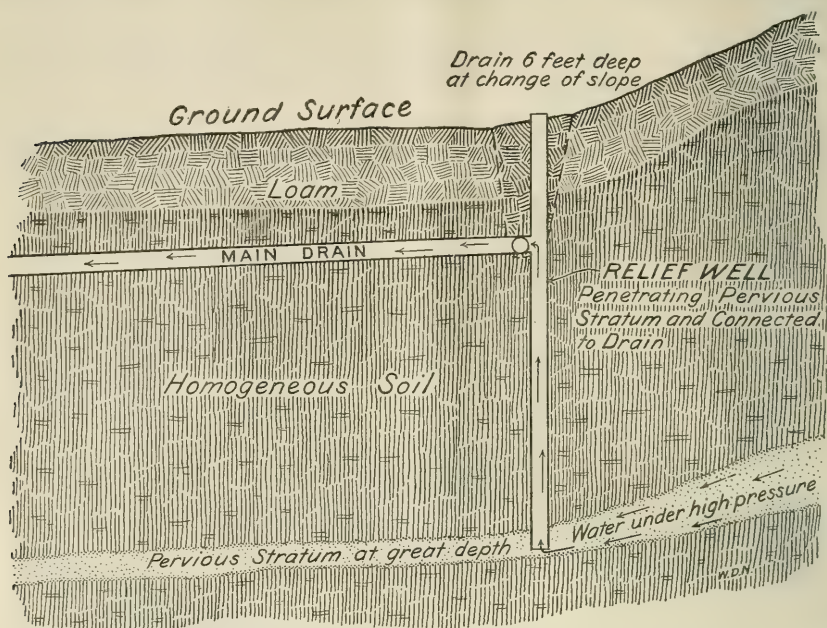


FIG. 13.—Section showing relief-well method applied to the drainage of lands receiving water from a deep pervious stratum.

coarse gravel. Relief wells in gravel, however, develop so much water that it is necessary to excavate a pit and build in a lumber or concrete box.

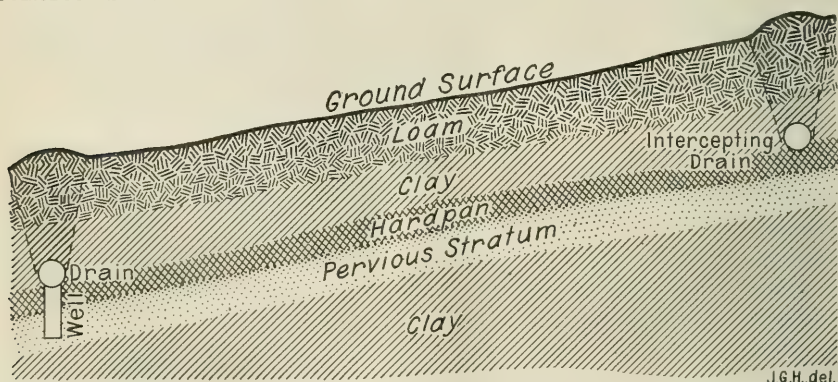


FIG. 14.—Section showing method of draining soils underlain by hardpan at a shallow depth by the use of relief wells. Intercepting drain cuts off seepage carried on the top of the hardpan.

DRAINAGE OF SOIL HAVING HARDPAN SUBSTRATUM.

Another case in which relief wells may contribute toward efficiency is shown in figure 14. In this case, which is frequently met with, a stratum of hardpan is found at a shallow depth, this being underlain

by a stratum of water-bearing material in which the water is generally under pressure. The hardpan is very difficult to penetrate with a trench, and the underlying material makes a poor bedding for tile. Moreover, the hardpan is practically impervious to water and to plant roots, so there is no need for deep drainage. The drain is laid on top of the hardpan and relief wells are bored through at frequent intervals, as shown in figure 14. The pressure causes an artesian flow which is carried away by the drain. Should there be seepage on top of the hardpan it may be intercepted at the upper edge of the tract.

DRAINAGE OF GRAVEL POCKETS.

Relief wells are especially useful in the drainage of soils underlain by gravel beds or pockets, particularly at the foot of benches, where the bottom land contains so much quicksand that it is difficult to lay a drain at the proper depth. Figure 15 shows the method of

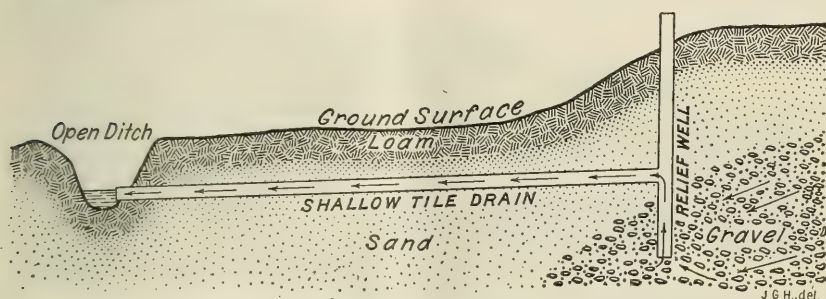


FIG. 15.—Section illustrating relief-well method applied to drainage of soils fed from gravel deposits.

application. The relief well should be sunk into the gravel. Enormous quantities of water are developed in this way; there is a case on record where a single well drained 100 acres of very wet land.

DRAINAGE OF SHALE KNOLLS.

Another application of the relief-well system is shown in figure 16 in which case the source of seepage is a buried shale knoll. The seepage is carried between the shale layers and is under pressure which is relieved by means of wells, these being connected to outlet drains.

APPLICATION OF THE UNIFORM SYSTEM.

There are some conditions where the uniform method of arranging the drains as used in the humid section is applicable. Among these is the case of a tract lying nearly level, having a fairly homogeneous soil or perhaps a substratum of sand at moderate depth, and receiving but little water from outside sources, the excess water being that due to the irrigation of the tract itself. The gridiron system, as shown in figure 17, is a most efficient plan under such conditions, the drains being placed from 200 to 450 feet apart. The latter figure

would apply to lands underlain by a sand stratum at from 4 to 6 feet below the surface. The drains should cut through this sand stratum, which itself thus becomes a great sheet drain. Under this arrangement three lines of tile to the 40-acre tract, or less than 100 feet of tile per acre, will drain fairly tough clay soil.

APPLICATION OF THE NATURAL SYSTEM.

The natural system of

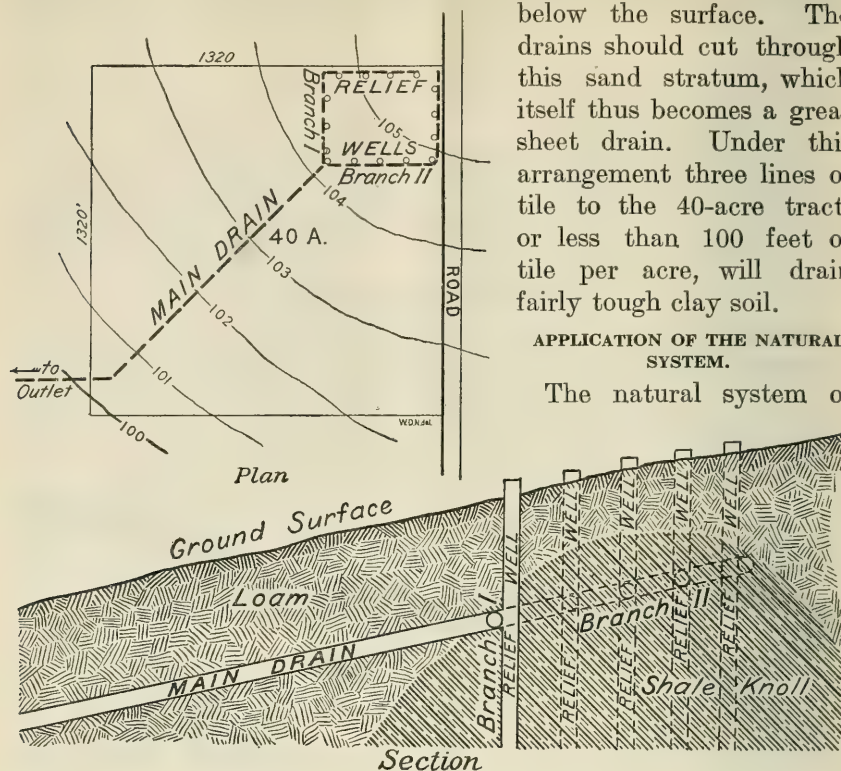


FIG. 16.—Plan and section showing method of draining where source of seepage is a buried shale knoll.

drainage is also applicable to irrigated lands. The principle involved in the application of this system is to assist the natural drainage and expedite its movement. To do this the drains are laid in the natural depressions and the ground water lowered in those locations, so that the movement of water toward the depressions is made more rapid. The system is especially applicable to lands underlain by gravel which occurs in undulating strata or beds.

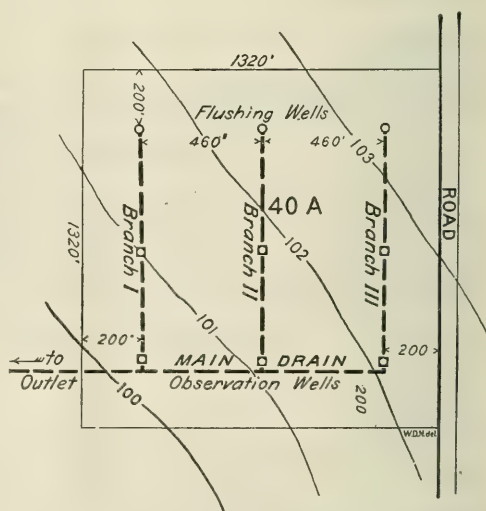


FIG. 17.—Sketch map showing application of a uniform system of drainage.

It has been found, however, that in the

irrigated region the seepage moves down the ridges more readily than down the depressions, so it is generally necessary to modify the drainage system by means of intercepting laterals cut through the ridges near the upper edge of the tract. These are indicated at *a*, *b*, *c*, *d*, *e*, and *f*, in figure 18.

APPLICATION OF DOUBLE LINES.

If the depressions are wide and the pervious material does not extend under the soil in the depressions, it will be necessary to employ two lines, one on either side of the depression, cutting into the pervious material. However, if it is possible to completely intercept the seepage by means of laterals at the upper edge of the tract, it will be cheaper to construct a single line down the center of the depression. Figure 19 shows how a double-line system would be located.

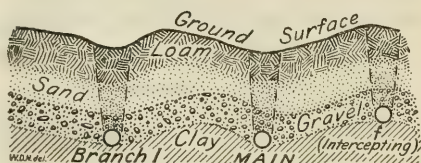
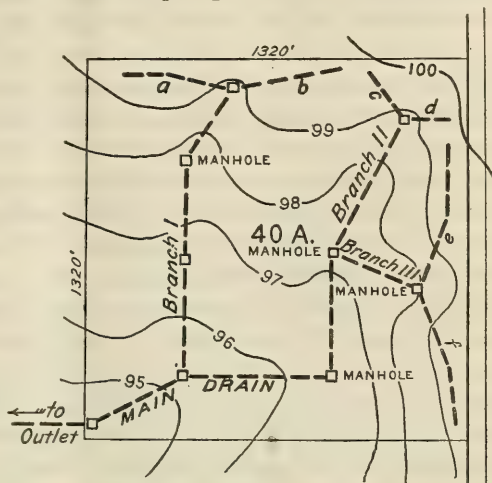


FIG. 18.—Plan and section illustrating application of natural system modified by intercepting laterals.

OTHER SPECIAL CASES.

In some localities the soil is underlain at shallow depths by lava or other rock formations, and the problem of drainage is exceedingly

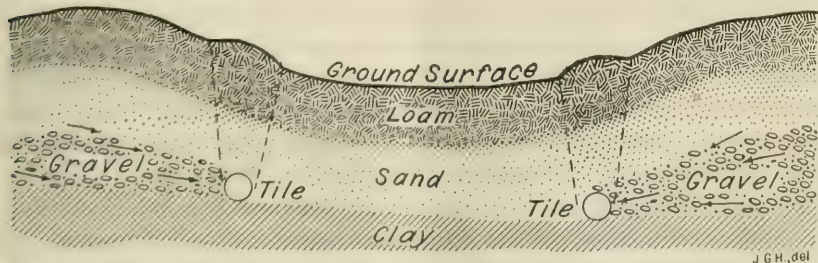


Fig. 19. Cross section showing modification of natural system in which two lines of tile are employed, one on either side of the wide depression and cutting through the pervious layer at the line of pinching out. A single drain in the center of this depression would accomplish very little.

difficult. Often the formation is so stratified and shattered that the natural drainage seems to be very good. Water enters the spaces very readily, however, and the rock masses themselves absorb but

little so that the ground-water table rises very rapidly when irrigation is applied and soon creates a demand for drainage. The damaging water must be cut off as it leaves the rock formations and before it enters the soil, or it may be tapped by means of relief wells.

Another situation that presents difficulty is that in which the irrigation canals have been constructed in old watercourses and natural drainage channels. These channels are often higher than the surrounding lands, due to the fact that they have overflowed from time to time, and the soil adjacent to them is coarser than that at a distance. Seepage from the canals waterlogs the adjacent soil and causes alkali salts to appear at the surface. Waste water and seepage from irrigation of the land find their way to the depressions and form ponds, or swamp the farm lands. To remedy these conditions, drains must be constructed through the lower portions to carry off surface water, waste water, and seepage, and to provide an outlet for tile drains on the higher portions. Intercepting drains must also be constructed parallel with the irrigation canals, to catch the direct seepage. It is usually feasible to construct these in the borrow pits adjacent to the irrigation canals. The main outlet drainage canals should not be placed in such locations, however, as they would not then afford an outlet for tile systems nor take care of the water that reaches the depressions.

CONSTRUCTION OF DRAINS.

The soils of the arid region are usually semi-fluid when wet, due largely to the absence of humus, and the construction of drainage systems therefore often requires the exercise of considerable patience and ingenuity. Special methods and devices have been called for and special machinery has been needed to overcome these difficulties.

OPEN CANALS.

In the construction of open canals in the irrigated section it has been found that the use of teams and scrapers is generally not feasible, owing to the considerable depth that must be obtained and to the miry condition of the soil. Hand labor is equally out of the question, owing to the excessive cost. The most satisfactory method of handling the work is by means of some efficient excavating machine. A number of these machines have been developed, but few of them are suitable for work in the irrigated section. A discussion of the comparative merits of the different machines is not within the scope of this paper. In general, the choice of the type of machine should be left to the contractor or other party doing the work.

Construction work should always start at the outlet of the drain and proceed up the slope, so that the water developed will drain away.

The spoil should be placed well away from the channel and may be deposited on either or both sides. Openings in the spoil banks should be left wherever lateral or waste ditches are to enter. The contractor should be required to give the canal as true a form as possible, as irregularities are likely to become more pronounced. It is well to excavate a little below grade to allow for silting and spalling. If it is found impossible to give the banks the proper slope, owing to the bad condition of the soil, it is well to excavate in terraces and leave the final form to the action of the elements. As a rule it is not advisable to attempt to cut out a canal by means of water, but this has sometimes proved effective where the fall was sufficient.

Little clearing for right of way is required in the irrigated section and little rock is encountered. Rock and frost should be broken by means of dynamite before an attempt is made to use a bucket.

COVERED DRAINS.

In installing covered drains either hand labor or trenching machinery may be used. On small projects hand trenching is frequently cheaper, but on larger projects the machine generally can do the work more rapidly and economically. In either case methods and devices adapted to the nature of the soil and to other local conditions must be employed.

If hand labor is used it is necessary to operate with small gangs, never more than a half dozen men to the line, as the trench must be opened from top to bottom as rapidly as possible and the tile laid and blinded before caving takes place. The men must work as closely together as is practicable; and it is generally advisable to do rapid, systematic work for a short time or until a given length of drain is completed, and then to rest for a few minutes and be prepared for another vigorous attack. Each man should remove a spading and move backward. The man removing the last spading should also grade the trench bottom. He should not step on the finished bottom, and no one should stand near the edge of the trench. The tile should be laid at once and should be blinded by means of a few inches of earth caved from the edges of the trench. If the banks tend to cave off in large chunks or slabs it will be necessary to brace them apart with planks separated by stout crosspieces or by trench jacks.

A very troublesome condition is that in which the presence of a wet, pervious stratum near the bottom of the trench causes a lateral and upward movement of the soil in the bottom of the trench. In such a case it is necessary to provide a tight cribbing to shut out the oozing material. A design for such a cribbing is shown in figure 20. It consists of two heavy timbers, held apart by means of trench jacks, behind which is driven lumber sheeting properly matched and beveled at the lower ends to insure a tight fit. The sheeting may be

driven by means of a heavy maul and may be removed by a three-legged derrick and a special grabhook, as shown in the figure.

If the soil in the bottom of the completed trench be so soft that it will not support a man's weight, boards should be laid under the tile to keep them in line and on grade. For large-sized tile the planks should be built into a triangular trough; or, if conditions are exceedingly bad, piles should be driven and planks secured to them in the form of a cradle. Under such conditions it is often advisable to employ sewer pipe in place of drain tile, as the bells aid in keeping the line intact. Second-quality pipe is suitable and may generally

be purchased at about the same cost as drain tile. Under ordinary conditions, however, the use of sewer seconds is not recommended, as the cost of freight and hauling is higher than for drain tile and the former are heavier and more difficult to handle. Also in stable ground it is necessary to dig out places for the bells, which considerably increases the cost of trenching.

The tile should be hauled and distributed in one operation and should be strung out end to end in a

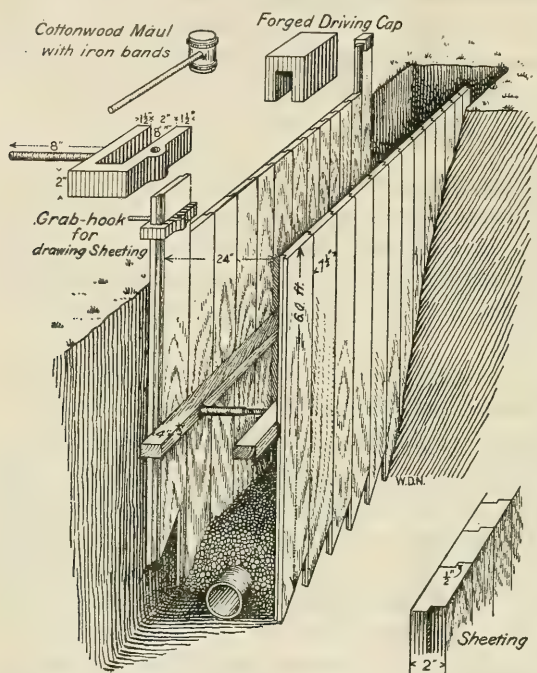


FIG. 20.—Method of sheeting trenches of moderate depth (Miller system).

line about 10 feet to one side of the proposed trench, with an occasional length laid down to allow for breakage.

Lines and grades for drainage work should be carefully established by surveys. To obtain a guide for hand trenching, a cord or wire should be stretched along the ground at one edge of the proposed trench, and to afford a convenient method of determining the proper depth at all points grade planks should be set up at each 50-foot station, as shown in figure 21. These planks should all be of the same height above the proposed grade of the trench, so that a cord stretched over the center of the trench will be at a uniform height above grade.

A pole gauge of this length may then be used to establish the grade at each tile, as shown in the figure. To ascertain the height above ground at which each grade plank must be set, it is only necessary to subtract the calculated cut at that station from the length of the gauge pole used, say 7 or 8 feet. For machine trenching, poles should be erected at frequent stations and target arms set at a uniform height above grade upon which sights may be taken by the operator of the machine. Tile should be laid true to grade and in straight lines. No attempt should be made to judge grade by the water in the trench. It is easy to vary a foot from the proper grade in a short distance in this manner. Tile should be laid within a half inch of true grade under ordinary conditions, and it is possible to do even better than this.

In laying tile the joints should be placed as close as possible. If the soil be semifluid and contains much sand and silt, it will be necessary to provide some means of keeping the oozing material from entering the tile joints. Almost all of the water entering the tile lines makes its way through the joints, practically none entering through the

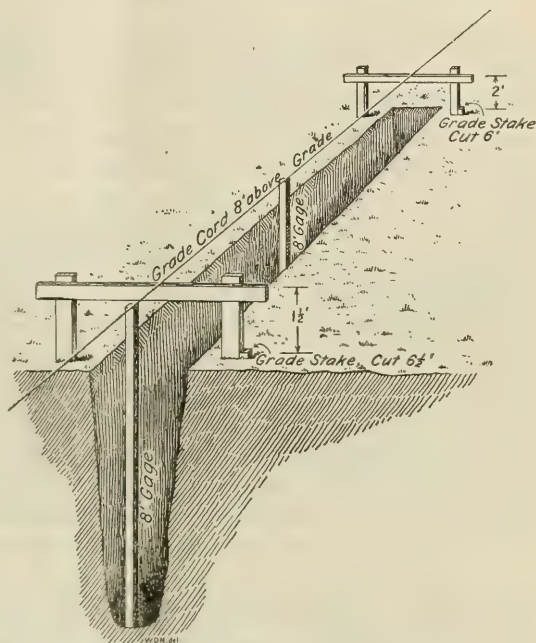


FIG. 21.—Method of establishing grade by means of cord and gauge.

walls of even the most porous tile, so the covering for the joints must provide for the ready passage of the water. Straw makes a very good filter when new, but it is likely to decompose and to form a sort of cement over the joints. Brush and willows are not satisfactory and render any subsequent removal of tile very difficult. Graded gravel, ranging from coarse sand to pebbles an inch in diameter, makes an excellent filter, but is not always available. Cinders also are satisfactory. Strips of burlap wrapped about the joints give good service. For genuine quicksand perhaps the best material is cheesecloth, which should be doubled once or twice and wrapped very carefully about the joint. This material soon disappears, but in the meantime the soil becomes compacted so that the purpose is served.

The more pervious material excavated should be placed adjacent to the tile. The backfilling may be done by means of a plow with three or more horses and a long pole evener, or by means of a scraper or "go-devil." All the spoil should be returned to the trench and should be banked over it so that future settling will not leave a depression over the drain.

Various types of trenching machinery, some of which are suitable for use on irrigated land, are on the market. The choice of machine may well be left with the contractor, however, and the question will not be discussed here.

MAINTENANCE.

If a canal is to retain its efficiency it must be well maintained. At least twice each year (more often if necessary) vegetation should be removed from the channel and banks, and such material as has fallen into the channel taken out. Any damaged places must be repaired to prevent further trouble. Tumbleweeds are a source of much difficulty, and it seems practically impossible to keep them out of drainage canals. They soon form serious obstructions and it is necessary to remove them at frequent intervals; this is generally done by men equipped with forks and rakes. Fortunately, these weeds generally disappear when drainage is accomplished. Perhaps the most difficult thing to deal with is "blow sand," which, during a high wind, may completely obstruct a canal in a few hours. From the very nature of the conditions maintenance is difficult and costly, and it follows that every endeavor should be made, during construction, to reduce the amount of maintenance necessary. When it is realized that the annual cost of maintaining open canals is often 10 per cent of the first cost, the need for correct design and careful construction is apparent.

A properly designed and well-constructed tile system requires little maintenance. Obstructions in the line, and vegetation that may develop dangerous water roots, must be removed. Holes and depressions in the backfilling must be filled and the burrowing of animals prevented.

A number of types of tile-cleaning devices have been developed. These are useful during construction in keeping the suspended matter in movement until the flow of water is large enough to create sufficient velocity to carry the material along. After the system is put in operation they may be used to clean out water roots that may have penetrated the tile line through the joints, or to clear the line of obstructions caused by sand or silt. One of these devices is in the nature of an auger, while another kind is built like a small hoe. For the removal of roots an apparatus involving a spiral cutter is used, or better still, a sort of wire brush. The latter is also useful in removing other obstructions and may easily be made by wrapping a piece of

leather belting around a cylindrical wooden rod, first having driven the belting full of nails of such length that the outside diameter of the completed brush is somewhat smaller than the inside diameter of the tile to be cleaned. These devices may be operated most conveniently by means of jointed sewer rods. The latter are made up in 3 or 4 foot sections which are fitted with couplings so arranged that they may be joined when two sections are placed at right angles, and are locked together when the two sections are in line. Working in a manhole 4 feet square, a man can easily put together and operate several hundred feet of rod in a tile line. Figure 22 shows a set of sewer rods and cleaning devices that have given satisfaction in operation.

SUBSEQUENT TREATMENT OF LAND.

While drainage is essential to the reclamation of water-logged and alkali lands, subsequent work is necessary for the complete redemp-

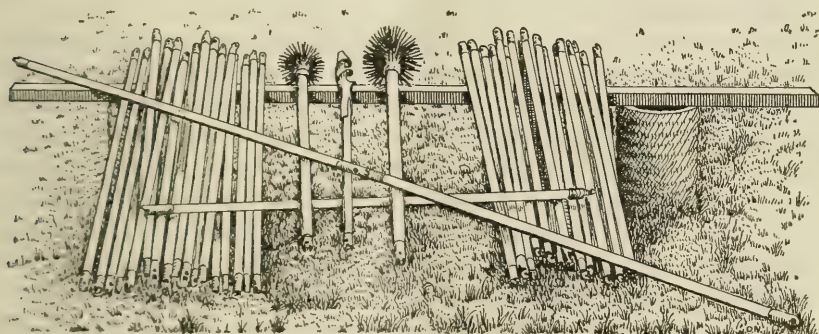


FIG. 22.—Sewer rods and tile-cleaning devices.

tion of the soil. The alkali salts which may have accumulated in the upper portions of the soil must be removed and the proper physical condition of the soil itself must be restored. Humus must be increased and it will be necessary that steps be taken to reduce evaporation, to maintain a downward movement of the salt solution, and to prevent any future rise of the latter.

The salts, being soluble, will usually be removed in time by the action of ordinary precipitation, and this latter is always an important factor in the subsequent treatment; however, the natural method is often too slow and is sometimes entirely ineffective, due to the fact that the precipitation is sufficient to saturate only a foot or so of the soil, and the excessive evaporation immediately returns the salts to the surface.

If expedition be desired, a good-sized stream of irrigation water should be turned on the land and allowed to percolate through the soil as rapidly as possible. This is best accomplished by diking the

land into checks and ponding the water as deeply as possible; each check should have as large an area as the slope of the ground and the amount of available water will permit. In no case should an attempt be made to flush the salts from the surface. They must be leached out and carried in solution downward to the underground reservoir. The desirability of using large checks and liberal quantities of water is due to the fact that capillary attraction is equally effective in all directions, and it is necessary to offset the tendency of the salts to move laterally in the soil and reappear on a higher or drier portion of the tract. For this reason it is required in flooding to make sure that all the surface is covered, even if knolls and ridges must first be leveled. It is generally advisable to thoroughly cultivate a field before the leaching process, but in some cases it has been found to be more satisfactory to flood first and then to cultivate as soon afterward as possible. If the subsoil be so impervious that the leaching water does not percolate readily, it may be necessary to resort to sub-soiling or blasting.

The quantity of salts removed by the leaching process is surprisingly large when considered as a total. It is not unusual to find a soil containing an average of 1 per cent of its dry weight in salts. Taking the average dry weight of the soil at 100 pounds per cubic foot and the depth of drainage at 6 feet, each cubic foot of the soil contains 1 pound of salts, and each 6-foot column of soil, 1 foot square, contains 6 pounds of salts. This amounts to 261,360 pounds, or over 130 tons of salts per acre, in a depth of 6 feet. For a 160-acre farm, this would amount to nearly 21,000 tons of salts.

Analyses show that the quantity of salts in the upper 6 feet of soil may be reduced 50 per cent by one flooding. But the discharge of $\frac{1}{4}$ cubic foot per second of water containing 1 per cent of salts, which is much higher than the average, would represent only 2,470 tons of salts per annum, and this takes no account of salts contributed to the tract by the irrigation water. From this it is evident that only a small portion of the salts is carried away by the drains and that by far the larger portion is leached into the underdrainage and redistributed below the drainage depth. This is a desirable condition, for it means that the mineral plant foods, which are also soluble in water, are not removed from the tract and wasted, but are left within reach of plant roots. It also means that the drainage water is sufficiently free from harmful salts to be useful for irrigation purposes. Indeed, conservation of the irrigation supply is being effected by applying to one tract water that has been drained from another, and in a few cases the drainage water is pumped back for the irrigation of the reclaimed tract itself.

The land should be cropped as soon as possible after reclamation; some crop which will shade the ground is preferable. If possible the

plants should be alkali resistant. It must be kept in mind that the salts are brought to the surface of the ground, in solution, by the capillary action of the soil particles and that they are deposited upon the surface when the solution is evaporated; hence the advisability of planting shading crops which reduce the evaporation. Artificial or soil mulches accomplish the same thing, and if shading crops are not planted, the soil should be kept well stirred. Subsoiling, besides assisting the leaching waters to percolate to the drains, breaks up the capillary columns and retards the upward movement of salts.

Alfalfa hay is a staple crop everywhere in the irrigated region. The alfalfa plant transpires a great deal of water, shades the ground surface well, gathers nitrogen, which is usually deficient in reclaimed alkali soils, and provides a liberal amount of humus when plowed under. It has been shown by Thomas H. Kearney¹ that a mature plant withstands well the action of salts, but unfortunately the young plants are very tender and germination of seed is next to impossible if there be much salt present. Sweet clover, also, is resistant to alkali and possesses all the good qualities of alfalfa, except as to its value as hay. It makes good forage if kept pastured down and should be employed at first if the more valuable crops can not be grown. Bermuda grass is fairly resistant and makes a good pasture, but its use can not be recommended, as it is more difficult to get rid of it than to reclaim the land from an alkali condition.

Mr. Kearney has also shown that the sorghums, Kafir corn, milo maize, etc., are adapted to use on reclaimed lands. Field corn is fairly resistant in most sections. Of the small grains, barley is the most resistant; but it has been found that when newly reclaimed tracts are devoted to grain it should be planted in the fall, so that the plants may become sturdy before the salts are brought to the surface by excessive evaporation in the spring. Grain does not afford much shading and is of little benefit in reclamation beyond the value of the stubble as a source of humus when plowed under.

WHAT DRAINAGE ACCOMPLISHES.

As a result of draining, excess water, whether it be from precipitation, waste or irrigation water, or seepage, is removed from the soil and the ground-water table is permanently lowered. Fluctuations of the ground-water table are more injurious to plant life than is a permanently high-water table and, within certain limits, drainage prevents such fluctuations.

The removal of the excess water allows air to be drawn into the soil spaces and the proper equilibrium between air and moisture is thus maintained and the soil is made warmer. As a result of this, bacterial activity is increased and more plant food is produced. Moreover,

¹U. S. Dept. Agr., Farmers' Bul. 446.

the root depth is increased so that both the available plant-food supply and the available moisture are increased by drainage.

The downward movement of water through the soil leaches out the excess of harmful salts, and this is one of the most important functions of drainage in the irrigated section. The movement of water also develops the pores of the soil, so that the physical character of the latter is improved.

Drained lands may be plowed earlier than undrained lands; thus the season is made both earlier and longer. An indirect result of this, which is of great importance in some localities, is that most of the irrigation may be done earlier than is usual and before the water supply becomes reduced. Moreover, drained lands require less irrigation water than undrained lands, and the water discharged by the drains may be employed for the irrigation of other areas, so that drainage practically increases the available irrigation supply.

Drainage performs an educational function in that it causes men to consider the use of water, to realize the vast difference between scientific irrigation and mere "watering," and to improve their methods of irrigation, resulting in a reduction in the amount of water used and in the subjugation of additional arid lands.

Drainage improves the public highways, railway roadbeds, and power lines, as well as telegraph and telephone lines. It increases the stability of buildings and structures and serves directly and indirectly to promote health and economic conditions in many ways.

COST OF DRAINING.

A distinction must first be made between farm drainage and outlet systems. The latter are intended only to afford outlet facilities to farm drainage systems and are rarely designed to accomplish drainage directly. Farm drainage systems are designed upon the supposition that natural drainage outlets exist or that artificial outlets will be available. Manifestly, it is impossible to build an outlet system that will not accomplish some drainage directly, and this, of course, reduces the cost of farm drainage in the vicinity.

The cost of outlet drainage systems varies from about \$3 per acre to as much as \$15 per acre. In the latter case very little farm drainage will be necessary, and the system may prove more economical than one costing much less but requiring more farm drainage.

The cost of draining ordinary-sized farms having an average soil that is neither so hard as to require picking nor so soft that extreme trenching difficulties will be encountered, will range from \$10 per acre to \$20 per acre with the average between \$14 and \$15 per acre. If hardpan be present or if the soil is so finely divided and so wet as to be fluxible, the cost will run up to \$50 per acre and even more if much sheeting is required. In a few special cases, drainage of small

tracts in the midst of unreclaimed lands has cost between \$75 and \$100 per acre, but these costs represent situations that would not be encountered in regular operations.

In regard to costs per unit of length of drain it may be said that clay tile drains range in cost from about one-half cent per inch of inside diameter per foot of length in the smallest sizes, to about 2 cents per inch of inside diameter per foot of length in the larger sizes. Hand trenching for tile up to 12 inches in diameter under ordinary conditions ranges in cost from 7 to 15 cents per linear foot for an average depth of 6 feet, while trenching in fluxible or hard material will run up to 25 cents per foot. Rock work would, of course, be higher. When sheeting is required the work will cost 50 cents per linear foot and upward. Machine trenching is usually cheaper, there having been some jobs of 5-foot trenching taken as low as 4 cents per linear foot. As a rule, however, machine trenching costs at least \$1 per rod for average soils and depths.

COOPERATIVE DRAINAGE.

The unit cost of drainage decreases as the size of the tract increases. This is partly due to the fact that a system installed on a small tract receives water from without the boundaries of the tract, and accomplishes more or less complete drainage over a considerable area. Furthermore, the unit costs of all materials and operations are less on the larger projects, and the required capacity of the drains becomes relatively smaller as the unit becomes larger. Economy demands that tracts as large as possible be handled as units, and, where the land is owned by a number of persons, it is necessary that some sort of cooperation be effected. Cooperation by mutual agreement is usually difficult and sometimes impossible to secure, owing to an unprogressive spirit among some of the landowners. However, the legislatures of practically all the Western States have provided laws by means of which cooperative work may be done. In general, these laws provide for the formation of drainage districts and for their government, prescribe their powers and privileges, and outline the duties of their officers. The direction of the business of a drainage district is in the hands of a board of drainage commissioners who are either elected by the freeholders in the district or are appointed by the county commissioners or the district court, depending upon which is the recognized authority in the matter of forming drainage districts. The district is granted the right of eminent domain, and bonds may be sold to pay for the construction work. Contracts may be let and provision is made for the equitable distribution of the cost of the work. The county officers are empowered to collect assessments. The construction work is done under the direction of an engineer appointed by the commissioners.

The usual procedure is to present a petition to the court or board, stating that the lands are in need of drainage and that the benefits of reclamation will exceed the sum of the damages caused and the cost of the work. Hearings or elections are held after due notice has been given, and the district is organized as a legal institution. In most States the organization of such districts is so easily effected, and operation under the law so comparatively simple, that it is advisable to make use of this means of carrying out the work.

CONCLUSION.

That the drainage of agricultural lands is an important factor in the future development of the irrigated section is shown in the alarming proportion of the lands that have been brought under irrigation which are now unproductive by reason of water-logging and alkali. The reclamation of these lands can easily and economically be effected by drainage, followed by proper cultivation, cropping, and irrigation.

The methods to be employed in draining have been described and the need for careful study of the subsurface conditions before starting the work has been emphasized.

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Charles J. Brand, Chief.

March 19, 1915.

DEMURRAGE INFORMATION FOR FARMERS.

By G. C. WHITE, *Transportation Specialist.*

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INTRODUCTION.

The purpose of this paper is to present a digest of the demurrage laws and regulations that are in effect in each of the States on both intrastate and interstate traffic. As indicating how the agricultural industry is affected by existing regulations and practices in the matter of car supply and the marketing of farm products, the salient points of each code have been compared and contrasted, one State with another, and the State codes with the uniform code or national car-demurrage rules. For ready reference the principal provisions of the various codes have been tabulated and are included in an appendix.

DEFINITION AND HISTORY OF DEMURRAGE.

Demurrage is a term applied originally before the days of railroads to the money penalty collected for undue delay in discharging the cargo of ships. It is to-day applied also to the charge made by railroads against shippers for the detention of cars beyond a certain specified time, called free time. The collection of demurrage was first inaugurated in the United States about 1887. From its being applied first by a few roads at badly congested terminals it has come to be applied universally on all roads at all stations.

NOTE.—This bulletin, while intended especially for farmers and shippers of farm products, should be of interest to shippers of all commodities and to transportation men generally throughout the entire United States.

THE FARMER'S INTEREST IN DEMURRAGE.

During the fiscal year ending June 30, 1912 (the latest for which statistics are available), products of agriculture amounted to 11.27 per cent of the total tonnage of all commodities handled by the railroads of the United States.

This percentage is exceeded only by products of mines, which were 49.09 per cent of the total tonnage, manufactures, 13.47 per cent, and products of forests, 17.11 per cent. Products of mines, products of forests, and 8 of the 13 commodities classed as manufactures will load heavier per car on the average than any of the 8 commodities classed as products of agriculture, with the possible exception of grain.

Regarded absolutely, the tonnage of agricultural products is great and the shippers of these products are interested in an adequate supply of cars. To move a given tonnage of agricultural products requires a greater number of cars than to move the same tonnage of the heavier loading commodities. Relatively, therefore, shippers of agricultural products are more interested than other shippers in the supply of cars. In addition, in agriculture there is a greater number of shippers for a given tonnage moved than in either the mining, manufacturing, or lumber industry, so that, measured by the number of people directly affected, the interest of agriculture in car supply is greater than that of other industries. The very nature of the business and the character of the product offer additional and peculiar reasons for agriculture being more vitally interested than any other industry in car supply and car efficiency, both of which depend directly on demurrage.

Unlike forest products, mineral products, or manufactures, agricultural products are seasonal. Harvest time brings the greatest demands on the roads for cars. Lumber and minerals may be stored in the open. Manufactures requiring protection from the weather are provided, for the most part, with ample storage facilities. Grain must move when harvested because of lack at points of production of storage facilities that will protect it against the risks of weather. Aside from the question of storage, most fruits and many vegetables must move as soon as harvested because of their perishable nature.

Lack of cars may mean to the farmer a total loss of his year's labor. To other classes it means inconvenience, delay in sales, and possibly a partial loss, but not a total loss. To the farmers of the country, then, the entire question should appeal strongly. They should be prepared to consider all phases of it. Their influence should be felt in securing regulations wisely planned and conducive to the best interests of commerce as a whole. Exacting from the railroads long periods of so-called "free time" for the loading and unloading of cars is a temporary expedient at best. In reality there is no such

thing as "free time." Every hour beyond that actually needed for loading and unloading cars is costly and usually the cost is borne ultimately by the man who clamors most loudly for more "free time."

REGULATION BY THE STATES.

As in the case of other practices of the railroads, the collection of demurrage came to be attended with so many discriminations in favor of the big shippers that one State after another took up the question. Forty-five of the 48 States—all except Delaware, Utah, and Wyoming—have a railroad commission or similar body exercising regulatory powers over the railroads.

In 12 of the States—Alabama, Arkansas, Colorado, Connecticut, Kansas, Minnesota, Missouri, Nebraska, New Jersey, North Dakota, South Dakota, and Vermont—demurrage is regulated by statute. The Connecticut statute merely provides four days free time for loading and unloading, but in actual practice the uniform demurrage code¹ is applied on State traffic. The Vermont statute makes the same provision as to free time, but in other particulars the uniform code applies. In some States—California, Texas, and Wisconsin, for example—demurrage regulation is partly by statute and partly by orders of the commission, or the statute empowers the commission at its discretion to modify the details of the statute. States of that kind are listed in the appendix as regulating demurrage by orders of the commission.

In 23 of the States—Arizona, California, Florida, Georgia, Indiana, Iowa, Kentucky, Louisiana, Maryland, Michigan, Mississippi, Montana, New Hampshire, North Carolina, Ohio, Oklahoma, Oregon, South Carolina, Tennessee, Texas, Virginia, Washington, and Wisconsin—demurrage is regulated by positive orders of the commission. In the following 10 of these States the commission has adopted the uniform code for intrastate traffic: Indiana, Iowa, Kentucky, Louisiana, Maryland, New Hampshire, North Carolina, Ohio, Tennessee, and Wisconsin.

In Nevada the roads apply the uniform code on State traffic, which the State commission has approved and recommended, but has not made compulsory. The commissions of Maine, Massachusetts, and Rhode Island, in so far as the regulation of intrastate demurrage is committed to them, have accepted the application of the uniform code by the roads. The commissions of Illinois and Pennsylvania are authorized by statute to prescribe demurrage rules and regulations within their respective States, but up to the present time they have taken no action. The essential features of the uniform code,

¹ The code adopted by the National Association of Railway Commissioners, endorsed by the American Railway Association, and approved by the Interstate Commerce Commission. See section entitled "Interstate Regulation" on page 4.

however, are applied in both States on State traffic. In Idaho, New Mexico, New York, and West Virginia the subject is covered neither by statute nor orders of the commission. However, the roads operating in these States pretty generally apply the uniform code, which, in practice, so far as the regulation of demurrage is intrusted to the respective commissions, amounts to State regulation by the adoption of the uniform code.

Neither Delaware, Utah, nor Wyoming has a railroad commission nor is there any statute relating to demurrage, but the roads operating in these three States apply the uniform code on State traffic.

It is seen then that in 24 of the States the uniform code is in actual operation on purely intrastate traffic. In the other 24, while the State regulations to a greater or less extent differ from those of the uniform code, many, if not most, of their essential features are the same as the corresponding provisions of the uniform code. Doubtless the commissions of some of the States that have not adopted the uniform code would do so if their statutes permitted. On the whole it would appear far preferable to have demurrage regulated by orders of a commission than by specific statute. Such an arrangement permits greater flexibility and makes it possible to adopt changes more readily as changing traffic conditions demand.

INTERSTATE REGULATION.

Demurrage on interstate shipments is subject to the jurisdiction of the Interstate Commerce Commission and all tariffs prescribing demurrage rates and regulations affecting such shipments must be filed with that body. While the Interstate Commerce Commission had authority to prescribe a code of demurrage rules and to require all of the roads to adopt them, the authority was never exercised. The question was discussed from year to year in the annual meetings of the National Association of Railway Commissioners and in 1908 a committee was appointed "to frame a uniform code of demurrage rules." This committee consisted of Mr. Lane of the Interstate Commerce Commission and one representative from the railway commission of each State. The actual work of drafting a code of rules was intrusted to a subcommittee of five. The subcommittee sought the assistance of practical demurrage men in the person of the managers of two of the leading demurrage bureaus of the country, and of Mr. Arthur Hale, chairman of the committee on car efficiency of the American Railway Association. After much study and public hearings the code adopted by the subcommittee was approved by the general committee and in turn adopted by the Association of National Railway Commissioners at its annual session in Washington, D. C., in November, 1909.

This code, known as the "National Car Demurrage Rules," or "Uniform Code," was approved by the Interstate Commerce Commission in December, 1909, and indorsed by the American Railway Association in January, 1910. Since that date changes in the code have been made by the adoption of amendments by the American Railway Association and their subsequent approval by the Interstate Commerce Commission. The association adopted a revised set of rules in May, 1912, which was approved by the commission in June of the same year. In November, 1912, and again in December, 1913, the association adopted modifications of individual rules and the commission shortly thereafter approved the changes. Additional changes are in progress at the present time through the same channels. None of the changes has been radical. The fundamental features of the code, as adopted in 1909, still remain.

The Interstate Commerce Commission's approval has always been based on its recognition of "the great benefits to be derived from uniformity in car-service rules" and its desire to lend its influence to the movement for such uniformity. Even with this general approval it is still necessary for the roads to publish the demurrage rules and regulations in tariff form and file them with the commission before they can become legally effective. Approval by the commission in this way does not preclude that body from entertaining and determining any complaint that may arise in the practical application of the rules.

PROVISIONS OF THE UNIFORM DEMURRAGE CODE.

Following is a brief summary of the provisions of the Uniform Code:

CARS SUBJECT TO RULES.

Rule 1 begins with the broad proposition that all "cars held for or by consignors or consignees for loading, unloading, forwarding directions, or for any other purpose" are subject to demurrage rules. Exception is made of cars loaded with live stock; of empty cars placed for loading coal at mines or mine sidings, or coke at coke ovens, and cars under load with coal at mines or mine sidings, or coke ovens; and of empty private cars in storage.

Cars loaded with live stock are excepted for the obvious reason that they are never held beyond the free time and their exception thus obviates the necessity of a great deal of unnecessary accounting. It is to be observed that cars ordered for the loading of live stock are subject to demurrage rules.

Cars for loading coal and coke and cars under load with these commodities awaiting billing are excepted, as it has been found that proper car distribution rules will take care of the difficulties formerly

experienced with this class of equipment. The question of its equitable distribution has been before the Interstate Commerce Commission many times until a code of rules has been evolved that does justice to all and avoids discrimination in periods of car shortage.

It would appear to be altogether unnecessary to make an exception of empty private cars in storage. The exception is rather an explanation of the status of private cars and is to be read in the light of the history of their development and the relations between private car owners and the railroads. Under the introductory clause of rule 1 private cars in storage would be excepted, since, under those circumstances, they are not "held for or by consignors or consignees." The rule and its explanatory notes go into details explaining that private cars are subject to demurrage rules while in railroad service whether on carrier's or private tracks. "Railroad service" is carefully defined both as regards private cars on private tracks switched by the carrier and on private tracks of an industry performing its own switching service. Quotation of the whole paragraph will make the matter entirely clear.

Empty private cars are in railroad service from the time they are placed by the carrier for loading or tendered for loading on the orders of a shipper. Private cars under lading are in railroad service until the lading is removed and cars are regularly released. Cars which belong to an industry performing its own switching service are in railroad service from the time they are placed by the industry upon designated interchange tracks and thereby tendered to the carrier for movement. If such cars are subsequently returned empty, they are out of service when withdrawn by the industry from the interchange; if returned under load, railroad service is not at an end until the lading is duly removed.

The right of carriers to collect demurrage on loaded private cars standing on private tracks, where cars and tracks are of the same ownership, makes impossible any discrimination in demurrage practices. It was contested in the case of *Procter & Gamble v. Cincinnati, Hamilton & Dayton Railroad* and decided November 14, 1910, by the Interstate Commerce Commission in favor of the railroad company (19 I. C. C., 556). On appeal the view of the commission was later sustained by the United States Supreme Court (225 U. S., 282).

Attention should be called here to the fact that empty cars of railroad ownership may not be retained under the guise of storage on private tracks of industries performing their own switching service. Loaded cars of railroad ownership received by such an industry are subject to demurrage rules until returned by the industry to the interchange track.

FREE TIME ALLOWED.

Rule 2 allows 48 hours for loading and unloading all commodities. Twenty-four hours are allowed in holding cars for switching orders,

for reconsigning, for surrender of bill of lading or payment of freight charges when cars are for delivery to or forwarding by a connecting line, for inspection and grading in transit, for completion of load or for partial unloading in transit, and for customs entry and government inspection of shipments in bond. Cars containing freight for transshipment by water will be allowed such time as the individual tariffs of the roads interested permit.

COMPUTING TIME.

Rule 3 excludes Sundays and holidays in the computation of time and provides that the following Monday shall be excluded when a holiday falls on Sunday. Free time begins to run from the first 7 a. m. after empty cars are placed for loading, after notice of arrival of cars held for orders, after placement and notice of arrival of cars for unloading on public-delivery tracks, and after actual or constructive placement of cars for unloading on other than public-delivery tracks. On loaded cars for industrial plants performing their own switching service, time is computed from the first 7 a. m. after actual or constructive placement on the interchange track until their return thereto by the industry. The underlying idea is that time shall be computed from the first 7 a. m. after placement and notice.

NOTIFICATION.

Rule 4 provides that notice shall be given the consignee within 24 hours after the arrival of cars. Notice shall be in writing or as otherwise agreed upon between the carrier and consignee, and shall include such information as point of shipment, car number and initials, contents, and, if shipment has been transferred en route, number and initials of the original car. Delivery of cars on private tracks or industrial interchange tracks constitutes notification to consignees taking delivery on such tracks.

PLACING CARS FOR UNLOADING.

Rule 5 defines "constructive placement" and its enforcement breaks up the discrimination formerly practiced in favor of industries doing their own switching and of those consignees who sought delay and more time by ordering cars to tracks that they knew were occupied. Cars for industries doing their own switching will be considered as delivered, and the free time will begin to run when they are tendered the industry and written notice served to that effect, even though the industry may refuse or fail or be unable to remove them from the interchange track. The former practice of free time beginning to run only after the industry has announced its readiness to receive the cars is abolished. When, from causes beyond the carrier's control, cars can not be placed on tracks designated by consignees they will be placed on the nearest available track and written notice served to that effect.

CARS FOR LOADING.

Rule 6 defines "constructive placement" of cars for loading, specifying that free time shall begin to run when cars are held on orders of the consignor and written notice served of all cars that can not actually be placed because of conditions attributable to the consignor. On all cars placed and not used demurrage will be assessed from the first 7 a. m. after placement, with no free time allowance.

DEMURRAGE CHARGE.

Rule 7 provides a charge of \$1 per day or fraction thereof after the expiration of free time till cars are released.

CLAIMS.

Rule 8 makes provision for an extension of time when it is impossible to load or unload on account of weather conditions or when, from the nature of the freight, serious injury would result to it from loading or unloading under adverse weather conditions. Allowance is made also for the bunching of cars, that is delivering the consignor cars in accumulated numbers in excess of his daily orders or delivering the consignee loads in accumulated numbers in excess of daily shipments. Demurrage may not be collected when unloading is delayed due to consignee declining to pay freight charges in excess of the correct amount. In addition, delayed or improper notice by the carrier, railroad errors preventing proper tender or delivery, and delay due to United States customs authorities, operate to extend the period of free time.

AVERAGE AGREEMENT.

Rule 9 covers the "average agreement" and provides that the demurrage charge shall be computed on the basis of the average time of detention of cars during each month. The average time is determined by allowing one day's credit for each car released within the first 24 hours of free time (except in the case of completion of load or partial unloading in transit) and entering a debit of one day against each car detained 24 hours or fraction thereof beyond the free time. No single car can take advantage of more than five days' credit in cancellation of its debits and after a car has accrued five debits the charge of \$1 will be made for each subsequent day of detention, including Sundays and holidays. At the end of the month a balance will be struck between the debits and the credits and \$1 collected from the consignee for each debit in excess of the credits. Should credits exceed the debits no payment is made to the car user. The account of debits and credits is closed for each month and no excess of credits for any one month may be carried forward to the next month. Shippers taking advantage of the average agreement may not at the same time take advantage of the provisions of rule 8 making allowance for weather interference and for bunching.

APPLICATION OF THE RULES.

These regulations apply, of course, to all shippers alike. None was designed to favor any particular industry, as appears to be the case in some of the State codes. However, the exclusion of Sunday in rule 3 and the provision for weather allowance in rule 8 are possibly of greater advantage, on the whole, in rural communities than elsewhere.

The average agreement in rule 9 is of no advantage to the farmer for the reason that he is shipping more than he receives. Its abolition would decrease car detention and thereby benefit the farmer as well as other car users. It is under attack from many quarters on the ground that it enables industries to detain unduly inbound cars of raw material on credits accrued on outbound cars of finished product, which are loaded to fill orders and would be loaded just as promptly in the absence of an average agreement.

EXCEPTIONS TO THE UNIFORM CODE.

Such are the provisions of the code of National Car Demurrage Rules, which are applied on interstate business throughout practically the entire United States and on intrastate business in 24 of the States. Some few exceptions are made here and there, and attention is called to the fact that there is not absolute uniformity in every particular in all sections of the country. The principal exceptions are noted below. They are for the most part of a minor nature and not such as to destroy the generally uniform character of the rules.

The free time on shipments for transfer to water carriers will vary with different railroads, for different commodities, and at different ports. Some of the lines, members of the Chicago Demurrage Bureau and of the Missouri Valley Demurrage and Storage Bureau, make a track storage charge in addition to the demurrage charge. Members of the Intermountain Demurrage Bureau, operating in Utah, Nevada, and Idaho, except empties placed for loading live stock, allow 96 hours for unloading ore and concentrates, with no weather allowance, and collect \$5 per day additional on certain high explosives. The Montana Demurrage Bureau allows 72 hours at Butte and East Helena for unloading interstate shipments of ore, concentrates, and eight other commodities. The Northern Demurrage Bureau, whose member lines operate in Minnesota, North Dakota, and South Dakota, makes special provisions for the inspection of grain and hay. The Pacific Car Demurrage Bureau, with 31 lines operating in California, Arizona, and New Mexico as members, exempt private cars on private tracks when the cars are used for the transportation of commodities which the owners of the cars produce or in which they deal, exempts empties for loading live stock, makes no allowance for weather conditions, allows 24 hours only for the unloading

of tank cars, and collects \$3 per day on all traffic in Arizona and California and on tank cars in New Mexico. In some sections a maximum of seven credits is allowed under the average agreement and in others, in applying the average agreement, cars are divided into two classes, box (including refrigerator), and all other cars, and credits accruing on cars of one class may not be applied on cars of the other class.

The allowance of additional time for inspection and grading of grain and hay is necessary under conditions as they now exist, with different grades and standards effective in different cities and States. Grain is probably reconsigned more than any other one commodity and frequently must bear the burden of car delay in several markets. Instances are on record of its having moved through 15 different markets, in each of which it was subject to official inspection, before it was finally unloaded. This constitutes a serious burden on that commodity. Federal legislation fixing grades and standards for interstate shipments would undoubtedly render much of the present inspection and grading unnecessary. To that extent it would decrease the detention of cars now caused by frequent inspection and grading and thus relieve agriculture of one unnecessary burden.

The exemption from demurrage of cars ordered for loading live stock in the territory of the Intermountain Demurrage Bureau and that of the Pacific Car Demurrage Bureau offers an apparent advantage to the live-stock industry. A concession of this nature, however, is without doubt a disadvantage in the long run to the shippers themselves. It is true that this section furnishes few other commodities adapted to transportation in stock cars and that these cars are idle and in storage a great part of the time. It is likewise true that frequently cattle must be driven long distances from range to loading station and that it is sometimes difficult to determine accurately the day cars will be needed. However, it should be borne in mind that the movement of cattle is largely seasonal, that stock cars are none too plentiful and that when they are needed they are all in demand and everybody wants some of them. The imposition of an adequate demurrage charge would cause them to be ordered exactly when needed, to be used promptly, and released for other shippers.

A GENERAL SURVEY OF STATE CODES.

Even a casual examination of the statutes and orders of commissions regulating intrastate demurrage reveals the fact that many of them are loosely drawn and that some of them contain ambiguous and conflicting provisions. As a whole they are fair to the railroads. Most of them could have been improved as to clearness of expression had the assistance and cooperation of railroad men been sought in the

adoption of uniform technical terms. In some instances correspondence with a commission has developed the fact that the secretary at least did not have an adequate understanding of the subject of demurrage or of how the commission interpreted certain rules. Too many of them have promulgated regulations which, if not making directly for car inefficiency, at least do nothing to promote car efficiency. All of them serve as an index to the abuses from which shippers have suffered at the hands of carriers, as is evidenced from the incorporation in them of many provisions having little or nothing to do with demurrage.

Among such provisions are "reciprocal demurrage," storage regulations for less than carload shipments, limiting time of shipments in transit, methods of ordering cars, penalties for failure to receive cars promptly from a connecting line, giving preference in movement to shipments of live stock and perishable, making permissible a charge for the empty haul of a car ordered and not used, prescribing method of notice of arrival for shipper's order shipments, requiring carriers to notify consignor of refusal of shipment by consignee and making consignor liable for storage and demurrage charges after such refusal, providing that cars will not be placed or forwarded for shippers in arrears in payment of demurrage, requiring carriers to furnish grain doors, and other similar provisions.

The success of intrastate codes in promoting car efficiency will depend a great deal on the personnel of the individual State commission and on whether or not it can initiate complaints or can act only on complaints filed with it. The force of commendable provisions in State codes differing from the interstate code are entirely lost in dealing with cars containing, or ordered for, interstate shipments. Consequently the success of such provisions in increasing car efficiency will depend directly upon what proportion of the business in the State is purely intrastate. This will vary from a very high percentage in large States like California and Texas to a very low figure in small States like Delaware and Rhode Island. The proportions will depend to some extent upon the size of the State and its population, but to a greater extent upon what proportion of the State's products are marketed and consumed within the State.

There are no statistics available showing for the different States what proportion of the total tonnage handled by the roads of each State is purely intrastate business. Nor are there any figures available showing by States, what percentage of the total tonnage, either intrastate or interstate, consists of agricultural products. It may be of interest, however, to note that for the fiscal year ending June 30, 1912, agricultural products amounted to 5.65 per cent of the total tonnage handled by the roads in the East, 8.20 per cent of the total

handled in the South, and 14.90 per cent of the total handled in the West. These territorial divisions correspond roughly to the country east of the Mississippi and north of the Ohio and Potomac for the East, south of the Ohio and Potomac and east of the Mississippi for the South, and west of the Mississippi for the West. "Agricultural products," as used here, include grain, hay, tobacco, cotton, fruits and vegetables, live stock, and wool.

"RECIPROCAL DEMURRAGE."

As the business of the country increased and the supply of cars grew relatively less, it became imperatively necessary to take some steps to increase car efficiency. Old regulations were more strictly enforced and new regulations more stringent were put into effect. Shippers came to a realization of the fact that duties and responsibilities as between themselves and the railroads were mutual. They argued, "If we are penalized for delaying cars—that is, withholding them from other shippers who need them—the roads should be penalized for delay in furnishing cars—that is, withholding them from us who are shippers and need them. Let us therefore have 'reciprocal demurrage.'" The unparalleled car shortage of 1906 gave point to their arguments and the "reciprocal demurrage" laws of 1907 and subsequent laws and regulations are the result.

"Reciprocal demurrage," so called, is in effect on State traffic only, at the present time, in 21 States. It is provided for by statute in Alabama, Arkansas, Colorado, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin. Orders of the State railroad commission govern in Arizona, California, Florida, Georgia, Mississippi, Oklahoma, Oregon, South Carolina, Texas, Virginia, and Washington. It is not demurrage at all within the general meaning of that term, but it is a penalty imposed upon the carriers for failure to perform certain duties or to furnish certain services within a specified time. From the penalty being imposed at first for failure to furnish cars the principle has been extended to cover delay in accepting shipments and issuing bills of lading therefor, as soon as they are tendered for forwarding, failure to move shipments at a prescribed minimum speed, failure to give notice of arrival within a specified time, failure to have shipments ready for delivery to consignees within a stated time, and delay in receiving shipments from or delivering them to connecting lines. Practically all the statutes and orders provide that the imposition of the penalties prescribed shall be no bar to the collection of actual damages sustained under the common law.

The two chief points of interest to shippers in the various "reciprocal" codes are the time allowed carriers to furnish cars and the penalty imposed for failure to furnish within the time prescribed.

TIME ALLOWED FOR FURNISHING CARS.

Alabama allows from 2 to 10 days, depending on the number of cars ordered. Arizona and California allow 48 hours and up, depending on the number of cars ordered, and prescribe that orders may not be placed longer than 15 days in advance. Arkansas allows 6 days. Colorado and Mississippi allow 5 days. Florida allows 2 days for fruit and vegetables, 4 days for other commodities. Georgia, Missouri, and Virginia allow 4 days. Kansas allows from 3 to 10 days, depending on the number of cars ordered. Minnesota allows 48 hours for terminal points and 72 for intermediate points. North Dakota allows 72 hours. Oklahoma allows from 48 to 144 hours, depending on the number of cars ordered, while Oregon allows from 5 to 20 days. South Carolina allows 3 days for perishable commodities and 4 days for other shipments. South Dakota allows from 3 to 6 days and Texas from 3 to 8 days, depending on the number of cars ordered. Washington allows from 3 to 10 days, depending on the number of cars ordered, the place where they are wanted, and whether or not the road has daily service at that point, and shorter time is given for live stock and perishable freight.

The States that have gone most into detail in demurrage laws and regulations are agricultural States. While the time allowed carriers for furnishing cars, as shown above, seems excessive in some instances, attention is called to the fact that Florida, South Carolina, and Washington have made specific provision for agriculture by prescribing the shortest possible time within which cars must be furnished to move perishable commodities.

PENALTY FOR FAILURE TO FURNISH CARS.

In the matter of penalty imposed for failure to furnish cars within the prescribed time it is uniformly \$1 in all except eight of the States. In Texas it is 50 cents per day; in Florida, North Dakota, and Oregon it is \$2; in Arizona and California it is \$3; and in Arkansas and Kansas it is \$5.

RESULTS OF "RECIPROCAL DEMURRAGE."

The Interstate Commerce Commission holds that it has no authority to penalize carriers through "reciprocal demurrage." The imposition of such penalties was stoutly resisted by the carriers, but there is now no question of the right to impose them and little question of the benefits accruing therefrom to shippers. While it may not be possible or advisable for carriers to provide sufficient equipment for the maximum tonnage offered at the busiest season of the year, "reciprocal demurrage" has doubtless had the effect of bringing about some increase in the supply of cars, and it has at least done

away, to some extent, with the discrimination against the small shipper, in the furnishing of cars, as compared with the man controlling large tonnage. This has been of especial benefit to the farmer. In addition to enabling him to secure cars more promptly when needed, it has had a very powerful influence in awakening the conscience of the railroads to the needs of the farmer and in bringing the railroads to a fuller realization of the fact that their prosperity depends on the prosperity of their patrons.

It must be admitted, however, that "reciprocal demurrage" is open to the objection of making possible collusion between carriers and shippers whereby carriers may pay rebates, or purchase routing, through the medium of failure to furnish cars on fictitious orders. Similarly the payment of demurrage has been avoided by collusion whereby cars have been set out in transit and held at intermediate points till consignees were ready to receive them.

OTHER PROVISIONS OF THE STATE CODES.

THE DEMURRAGE RATE AND NORMAL FREE TIME.

The two most important features of any demurrage code are the time allowed for loading and unloading and the charge made for detention of cars beyond the free time. Under the uniform rules the free time is 48 hours and the charge \$1. In the 24 States regulating intrastate demurrage either by statute or orders of the railroad commission the charge is \$1 except in Oregon, California, and Arizona. In Oregon the charge is \$2 and in California and Arizona it is \$3. In Montana it is \$2 after the first 5 days after the expiration of free time.

The normal free time for loading and unloading is 48 hours in all the States except four. Florida allows 72 hours, Nebraska 36 hours, New Jersey 3 days, and Vermont 4 days.

ADDITIONAL TIME FOR UNLOADING.

In the matter of unloading, Alabama and Arkansas allow 72 hours on 13 specified commodities. Florida allows 96 hours on 9 commodities. Georgia allows 60 hours on coal. Michigan allows from 3 to 15 days on various commodities. Seventy-two hours are allowed on 5 commodities in Minnesota, on 10 in Montana, on 19 in South Carolina, on 2 in Texas, and on 14 in Virginia.

The agricultural products allowed additional time for unloading in Alabama, Arkansas, and Virginia are fertilizers and hay and the following commodities in bulk: cottonseed, cottonseed hulls, grain and potatoes. Alabama includes cottonseed meal also. The farmer derives an immediate benefit from the additional time allowed on fertilizers, and cottonseed products. Additional time on the other commodities give him a direct advantage only as he occasionally

has to purchase them. An indirect and remote advantage accrues when he is selling on commission such of them as grain, hay, or potatoes. The agricultural products on which additional time is allowed in Florida are cabbage, cottonseed, cottonseed hulls, fertilizer material, potatoes, and seed cotton. Minnesota grants additional time on fruit and vegetables. South Carolina provides more liberally for agriculture by granting additional time on bran, cottonseed, cottonseed hulls, cottonseed meal, fertilizers, fertilizer material, grain, hay, meal, mill feed, bulk apples, and bulk potatoes.

Additional time is allowed in some States to consignees located a certain distance from the station. In Alabama from 4 to 6 days are allowed for distances of 3 miles or more. In Arkansas a maximum of 5 days is allowed for 5 miles and over. Mississippi allows 5 days for distances of from 3 to 10 miles and 7 days for distances over 10 miles. Oklahoma allows 72 hours for distances greater than 5 miles. South Carolina allows more time for distances greater than 4 miles. Texas allows 96 hours for distances greater than 5 miles.

As a matter of practical business there is little justification for allowing additional time on certain excepted commodities. So far as the labor of loading and unloading is concerned, a carload of any of the special commodities mentioned above can easily be loaded or unloaded in the 48 hours allowed on other commodities. A sliding scale of time varying with the quantity of the carload is more reasonable, but in both cases the real reason for shippers wanting more time usually has no connection with the actual time necessary to load or unload a car. Usually it springs from a desire to shift elsewhere an item of expense that should properly be borne by the shipper's business.

At first glance the regulations of those States that base the length of time on the distance from the station would seem to be the most logical. A close examination, however, reveals the fact that none of them applies the principle consistently in detail. Texas, for instance, allows 96 hours for distances greater than 5 miles. If 96 hours is a reasonable period of time to allow for loading or unloading a car when the shipper is located 6 miles from the station, it is certainly not reasonable for a shipper located at a distance of 16 miles or 20 miles.

Instead of asking for long periods of "free time" in which to load and unload their carload shipments, and then using all of it merely because it is "free," it would be a distinct economic gain and an advantage to all shippers if the farmers would insist on some of the present periods being shortened and would use every effort to reduce car detention to the actual time needed for loading or unloading a car. Cooperative associations could solve the problem for those who live long distances from the railroad by erecting warehouses at a

common shipping point. Shipments received could be unloaded into these warehouses immediately on arrival and cars released. Hauling from the station could be done at the farmer's leisure. Freight for forwarding could be concentrated in the warehouse and cars ordered, loaded, and forwarded without delay when the entire shipment was ready to move.

Colorado, Kansas, Mississippi, Missouri, and Texas allow 72 hours for unloading cars loaded in excess of 30 tons. Nebraska allows 60 hours for the same tonnage and Oklahoma makes it 72 hours for cars containing more than 66,000 pounds.

When a consignee receives in 1 day more than 3 cars of freight taking track delivery, Florida allows 96 hours free time on each car in excess of 3, Georgia 78 hours, and South Carolina 72 hours. This is merely a variation of the provision in the national code in regard to bunching in transit.

When notice is given by mail, Arkansas allows 48 hours additional free time. Alabama, Florida, Georgia, Minnesota, South Carolina, and South Dakota each allow 24 hours additional free time under the same circumstances.

SPECIAL FEATURES OF STATE CODES.

Other features of different State codes are worthy of note. Alabama, California, Mississippi, Oklahoma, Texas, and Virginia exempt private cars on private tracks, and thus make possible discrimination in favor of owners and users of private cars which the national code is very careful to forbid.

Alabama allows 24 hours additional free time on certain commodities and additional specified time where the consignee is located 3 miles or more from the station. The fact that the additional free time, plus 24 hours, is not given when the long distance consignee receives one of the special commodities would seem to argue that granting the consignee under 3 miles an additional 24 hours on one of these commodities was not well founded.

Arizona and California penalize a carrier for failure to move cars received from a connecting line within 24 hours, but do not penalize the originating carrier for failure to move a car within the same period after receiving it from the consignor.

The Arkansas statute contains a most commendable section forbidding railroad employees to solicit tips for placing cars and applying the same penalties to shippers who offer and give tips to employees for prompt switching service.

The Colorado statute is so drawn as to make the capacity of the car rather than the quantity of its contents the determining feature in allowing 72 hours for unloading.

The Florida code appears to fix a different penalty for each case without reference to the question of simplicity and uniformity and the fact that the sole end to be attained is greater car efficiency.

Georgia, in common with a number of other States, makes penalties accruing to shippers payable only on demand in writing within a certain time. Under a fair system of "reciprocal demurrage" they should be payable and paid as promptly and with as little formality as demurrage charges due carriers from shippers.

Montana exempts from the operation of the rules cars loaded or to be loaded with wool.

The New Jersey statute is probably the briefest of any, merely providing the customary penalty of \$1 per day with 3 days of free time for unloading. Nothing is said as to detention of cars for loading and none of the other points usually in a demurrage code are mentioned.

The North Dakota statute provides that consignees may refuse shipments not delivered at destination within 60 hours after they are due to arrive, and in case of refusal carriers shall be liable for the value of the goods, plus actual damages. The same section contains another provision which could be used to provide for the payment of rebates by requiring the carrier to forfeit to the shipper 10 per cent of the charges due on a carload shipment for each 24 hours that the car is delayed in transit.

South Carolina provides that consignees 4 miles or more from the station shall have "sufficient time" by the exercise of "ordinary diligence" to unload cars.

The Texas statute provides a "reciprocal" penalty of \$25 per day for failure of carriers to furnish cars and failure of shippers to load or unload in 48 hours, such penalties to be "cumulative of and additional to" the demurrage charges prescribed by the State commission. Among the various regulations of the commission is one providing that carriers shall place cars on unloading tracks designated by the consignee within 24 hours after arrival. For each 24 hours' delay beyond this time the shipper shall have 5 additional hours of free time. Penalizing the delay under the reciprocal provisions would more effectively promote car efficiency.

The regulations of the Virginia commission allow from 24 to 36 hours for the weighing of cars on track scales after arrival at destination when consignees request weighing. The acceptance on Saturday afternoon by a consignee of personal notice of arrival of a shipment is construed as notice given on Monday prior to 6 p. m., thus making free time begin 7 a. m. Tuesday. Personal notice prior to 6 p. m. any other day makes free time begin 7 a. m. the following morning.

DEMURRAGE BUREAUS.

Prior to the Hepburn law of 1906 amending the act to regulate commerce, when discriminations of every kind were the order of the day and railroads adopted various devices as aids to keeping their own agreements with one another and as a partial protection against the importunities of favored shippers, many demurrage bureaus were formed on somewhat the same theory as that on which the weighing and inspection bureaus came into existence. A demurrage manager was located at a central point and given jurisdiction over a certain territory. All lines within that territory were members of the bureau and the manager was the joint employee of all the lines. He promulgated the rules of the member lines, supervised their enforcement, and decided disputed points. The plan was not very effective in enforcing demurrage regulations as a whole, as the big shipper still had his private understanding with the higher officials.

Since 1906 the States have taken up demurrage regulation and promulgated specific rules, requiring their publication in tariffs and making the State railroad commission the final authority on disputed points. The Interstate Commerce Commission requires tariff publication of definite rules governing interstate shipments. It is the station agent's duty to collect demurrage charges with the same degree of promptness as he uses in collecting freight charges. Public sentiment demands the enforcement of demurrage regulations and the roads no longer desire to evade them. Consequently many lines have found it more economical to handle demurrage matters through already existing machinery and many of the demurrage bureaus have been dissolved. This was true of the Texas Car Service Association and of many of the bureaus in Central Freight Association territory.

Doubtless others may be abolished in the future, but at the present time 20 of them are still in existence. In the appendix will be found a list of them. All important lines in the territory of any bureau are members of that bureau. The duties of the managers are for the most part administrative under existing tariffs and State regulations. In the case of the Chicago, the Intermountain, the Pacific, and the Pacific Northwest the bureau manager publishes and files the demurrage tariffs as agent for the member lines. In the other 16 cases the member lines issue individual tariffs.

Closely related to the demurrage bureaus is the New England Demurrage Commission, with headquarters at Boston. It was established as one of the results of a general investigation in 1910 by the Interstate Commerce Commission of demurrage practices in New England. All the lines in New England are members of it and, while each line publishes and files its own demurrage tariffs, a demurrage commissioner has general oversight of demurrage matters. The com-

missioner was designated by the Interstate Commerce Commission and appointed by the railroads "to arbitrate all doubtful or disputed cases growing out of the application of the demurrage rules, which the shippers or the railroads desire to refer to him." As an impartial investigator to whom both sides may refer, his efforts are to secure from the railroads their best possible service and from shippers cooperation by the prompt release of cars in order that commerce may be facilitated and that efficiency of transportation may be increased.

The growing importance of demurrage is being generally recognized. The necessity for a more careful supervision of it and for a closer study of the subject is making itself apparent in many ways. An example is the recent appointment by the American Railway Association of a demurrage supervisor for the State of Texas.

RECOMMENDATIONS OF DEMURRAGE OFFICERS.

The fact that the managers of the demurrage bureaus are dealing exclusively with only one phase of the railroad question puts them in a position to know the details of that one phase very thoroughly. Their opinions individually and their recommendations collectively, as the American Association of Demurrage Officers, are deserving of careful consideration and have had great weight in influencing demurrage practices. Communications addressed to each of them have developed the fact that 13 of them favor the abolition of the average agreement. Fourteen of them favor an increase in the demurrage rate. One advocates a \$3 rate on refrigerator cars, one the same rate on hay and straw, and four a \$3 rate on all cars. One suggests that the charge be assessed for Sundays and holidays after the expiration of the free time.

The rate of \$3 per day is suggested by the fact that that is the rate at present in effect on interstate shipments in Arizona and California. June 19, 1909, the California State rate was raised by statute from \$1 to \$6 per day. May 1, 1911, it was reduced to \$3 by order of the State commission. Records of the Pacific Car Demurrage Bureau showed greatest car efficiency under the \$6 rate and efficiency almost as great under the \$3 rate. In January, 1912, the manager of this bureau filed with the Interstate Commerce Commission a tariff raising the interstate rate to \$3. The commission, on its own motion, suspended the tariff. After hearings and much testimony, with little opposition from shippers, the case (I. & S. Docket Nos. 83 and 83A, 25 I. C. C. 314) was decided December 2, 1912, and the \$3 rate allowed to stand. The chairman of the commission dissented, holding that a rate of \$1 per day was sufficient, as a general rule, anywhere throughout the country. Another member held that the increased car efficiency on State traffic under a \$3 rate was due not to the rate, but to the activity of the manager of the Pacific Car Demurrage Bureau.

The manager of the bureau, in a statement issued February 14, 1914, comparing results in California with results in the territory of the Intermountain Demurrage Bureau, where the same roads operate, distinctly disclaims this and insists that to the rate alone are due the results of greater car efficiency.

CONCLUSION.

If, in times of acute car shortage, the shipper who needs cars and is unable to get them could actually see all the other car users at all the other stations in his immediate section who are taking from two to seven days to load and unload cars, when it could and should be done in as many hours, no doubt there would be a speedy reformation among car users and a radical revision of some of the demurrage regulations now in effect. If his vision could be enlarged so as to take in the entire country the effect would be magical. Most, if not all, of the difficulties experienced in connection with car supply and car detention and the demurrage remedies proposed to alleviate the evils of car shortage have arisen from a lack of breadth of vision on the part of shippers, railroad officials, and legislators.

No car user has any moral right to detain a car one moment longer than is necessary to load or to unload it. Unfortunately the proportion of shippers who take this view of the situation, when they themselves are the detainers, is very small. Every shipper holds this view when it is some one else that is detaining the car. Car users who detain cars through carelessness, indifference, or ignorance of the meaning of "car shortage" and "congested terminals" are few. The people responsible for car detention are that vast body of highly intelligent business men who find it more profitable to use cars for storage purposes than to provide other storage facilities. Other reasons for car detention by this class of shippers are comparatively insignificant.

It is not good business to use for storage, space which costs 50 cents per cubic foot to construct, when better storage space can be had for one-third that cost or less, and especially when the higher priced space can earn so much more as a freight car than as mere storage. Storage space does not need costly trucks, steel underframes, automatic couplers, and air-brake equipment. Shippers must realize that, from one point of view, they and not the railroads are the owners of the cars of the country. So long as they insist on using them as storage warehouses they must be prepared to pay the cost without complaint. Moral suasion has so far failed to induce them to construct their own storage warehouses when they could get apparently cheaper storage in freight cars. The next step in remedying car shortage should be to limit more closely the free time allowed and

to impose a demurrage charge sufficiently high to make storage in cars clearly unprofitable.

These statements are made as applicable to every class of cars, but it is recognized that refrigerator cars present some exceptions to the general rule. The fact that the lading of these cars is so frequently under refrigeration and that so many consignees are not provided with refrigerated storage space of their own increases the tendency to hold shipments in cars until sale is effected. The cost of renting refrigerated storage space, the cost of hauling to and from such plants, and the deterioration due to the hauling and to changes in temperature during the hauling are to be considered as against the demurrage charge. With the purpose of increasing its perishable tonnage, if not of monopolizing the carriage of perishable to some market, there are instances of where a carrier has in the past offered unusually liberal concessions to dealers in the matter of track sales privileges and the detention of refrigerator cars. Such practices discouraged the providing for themselves of storage space by dealers and consignees at a time when it could have been more cheaply provided than at present. The withdrawal of former concessions and the imposition of more rigid restrictions now are protested with some show of justice by interested car users.

On the other hand refrigerator cars are not in demand the year round to the extent that other classes of cars are. The tendency is to limit more closely purchases of them, and the supply of refrigerator cars is possibly more inadequate than the supply of any other class of cars. The contention that the perishable nature of its contents fixes a very brief maximum period that a refrigerator car can be held at destination under load is as forcible an argument for releasing the car all the more quickly as for allowing the maximum possible time at the ordinary demurrage rate. While it is being held under load at one market destination perishable commodities are ripening at many originating points of production and spoiling for lack of a refrigerator car in which to transport them to other markets in need of them.

Refrigerator cars are now paying the nominal demurrage charge of \$1 per day and, in some cases, additional charges for track storage. The proposal to impose higher and other charges, in addition to track storage and ordinary demurrage, as a penalty for the detention of refrigerator cars, is a move in the right direction. It will do more than anything else to solve the problem of shortage of refrigerator cars. It will also give an impetus to the erection by municipalities, railroad companies, and private capital of terminal markets with track connections and ample cold storage facilities. Cold storage for perishable commodities is necessary and the economy of providing it

as cold-storage space instead of in refrigerator cars would appear to require no argument.

Any discussion of a charge based on the value of a car is useless because of the impossibility of determining what the value is. The value of a car will vary with the kind of car, the commodity handled, the season of the year, the location of the business, and whether it is being considered from the standpoint of the interest of the owning road, the using road, or that of the owner of the lading. It is simply a question of whether it is cheaper for a shipper to use cars for storage than to provide storage elsewhere. It is a very simple matter to determine a rate that will make car storage unprofitable.

Every effort to increase the demurrage rate brings forth a loud protest from the misusers of cars on the ground that vested rights and long-established customs are being interfered with. No demurrage charge need be burdensome to shippers. As a rule, it is voluntarily assumed and can readily be avoided by prompt loading and unloading.

From one point of view the railroads are between the upper and nether millstone of the man who has the car and the man who wants it. Each abuses the road for the shortcomings of the other. In the last analysis of the case both are the same man, unable or unwilling to see that a car can not be a stationary warehouse and a movable vehicle at the same time.

The railroads would gladly forego all revenue from demurrage in return for prompt release of cars. In fact the charge is not intended as a revenue producer, but as a stimulant to speedy release of equipment. The excess of demurrage charges over the immediate cost of collection does not take into consideration the economic loss from car shortage and the economic waste involved in switching blockaded yards. This loss and waste it is impossible to calculate in terms of dollars and cents.

Under the totally inadequate demurrage charge prevailing throughout the greater part of the country there have grown up indefensible practices, altogether wrong in principle. This is especially true in the case of the coal brokers, grain dealers, commission men generally, and big manufacturing plants. In periods of acute car shortage and congested terminals there is an almost universal demand that carriers be compelled to increase their car supply, enlarge their terminal yards, and provide increased switching facilities, when it has never been shown that they are not already adequately equipped in these respects if cars were used for transportation solely and not used for storage warehouses. Increased expenditures for additional cars, more switch engines, and bigger yards mean increased interest charges which the commerce of the country must bear.

Farmers are not large receivers of carload shipments and many of the products which they forward are perishable and must on that

account be loaded promptly. To this extent then their responsibility for unnecessary car detention throughout the country is lessened. As has been shown, however, they suffer most from car shortages. Some of the State demurrage codes contain provisions apparently designed as special concessions in favor of the farmer. No doubt other industries would not very readily give up any special concessions in their favor on the strength of the farmer voluntarily giving up his. It would seem, however, the proper thing for farmers to insist on the elimination from all demurrage regulations of all special concessions in their favor. Then they could with greater force demand the abolition of concessions in favor of others. This would mean a minimum of car detention, more cars for all shippers, and greater prosperity for the farmer.

APPENDIX.

Below are two tables showing variations from the uniform code on interstate and intrastate traffic. The uniform code is taken as the normal and the only two features of it included are the free time allowed for loading and unloading and the demurrage rate. Time allowed for reconsigning, completion of load, and other purposes mentioned in rule 2 of the code are not taken into consideration here either under "normal time" or "additional time," nor are such features here considered in detailing the variations from the uniform code.

When no entries are shown in the various columns it is to be understood that the uniform code applies, or that the corresponding provisions of State codes are the same as those of the uniform code.

Table I contains a list of all the demurrage bureaus, together with the headquarters and a general description of the territory embraced in the jurisdiction of each one. This information is taken from the Official Railway Equipment Register. Some of the bureaus are confined to a particular State, as, for example, Montana, North Carolina, and Tennessee. However, no one bureau necessarily includes all the roads in any one State nor is any one State necessarily confined to one particular bureau. Tennessee has two bureaus within its borders, while Illinois has four. On the other hand a single road may be divided among several bureaus, the Santa Fe System, for example, having portions of its line under seven different bureaus. The Lake Superior Demurrage Bureau is confined practically to the two cities of Duluth and Superior. Some are shown as operating in a certain State when in reality they may include only a few stations on some particular road in that State. The Illinois and Iowa, as an example, has in Kentucky only the station of Paudeah on the Chicago, Burlington & Quincy Road.

Attention is called to the fact that the demurrage bureaus, on intrastate traffic within the various States, administer the provisions of the State codes. Consequently Table I shows variations from the uniform code on interstate traffic only.

Table II contains a list of all the States and shows which ones have railroad commissions. It shows also in which ones demurrage is regulated by statute and in which ones it is regulated by orders of the commission. As to "reciprocal demurrage" the three most important features are shown, namely: Time allowed carriers in which to furnish cars, the basis for extension of time where there is a sliding scale, and the penalty imposed for failure to furnish cars within the time allowed. Inasmuch as "reciprocal demurrage" applies on intrastate traffic only, all reciprocal features shown are necessarily variations from the uniform code.

TABLE I.—*List of demurrage bureaus, their headquarters and jurisdiction, and variations from the uniform code on interstate traffic.*

[Uniform code: Free time, 48 hours; demurrage rate, \$1.]

Demurrage bureau.	Headquarters.	Number of roads.	Territory embraced in States of—	Additional time.	Demurrage rate.
Alabama.....	Birmingham..	18	Alabama, Florida, Louisiana, and Mississippi.		
Central.....	St. Louis.....	15	Illinois and Missouri.....		
Chicago.....	Chicago.....	13	Illinois, Indiana, Michigan, and Ohio.		
Colorado.....	Denver.....	14	Colorado, New Mexico, and Wyoming.		
East Tennessee.....	Chattanooga...	12	Georgia and Tennessee.....		
Illinois and Iowa.....	Peoria.....	38	Illinois, Indiana, Iowa, Kentucky, Missouri, and Wisconsin.		
Intermountain.....	Salt Lake City	17	Colorado, Idaho, Nevada, Utah, and Wyoming.	(1)	(2)
Lake Superior.....	Duluth.....	7	Minnesota and Wisconsin.....	(3)	
Louisville.....	Louisville.....	11	Indiana and Kentucky.....		
Missouri Valley.....	Kansas City...	23	Illinois, Kansas, Missouri, Nebraska, and Oklahoma.		
Montana.....	Butte.....	8	Montana.....	(4)	
North Carolina.....	Raleigh.....	18	North Carolina.....		
Northern.....	Minneapolis...	14	Minnesota, North Dakota, South Dakota, and Wisconsin.		
Pacific.....	San Francisco..	31	Arizona, California, and New Mexico.	(5)	(6)
Pacific Northwest.....	Seattle.....	20	Idaho, Oregon, and Washington.....		
Southeastern.....	Atlanta.....	52	Florida, Georgia, and South Carolina		
Tennessee.....	Nashville.....	7	Tennessee.....		
Virginia and West Virginia.....	Richmond.....	19	Kentucky, Maryland, Ohio, Tennessee, Virginia, and West Virginia.		
Western.....	Omaha.....	18	Iowa, Nebraska, South Dakota, and Wyoming.		
Wisconsin.....	Milwaukee....	18	Michigan and Wisconsin.....		

¹ Allows 96 hours for unloading ore and concentrates.² Charges \$5 per day on certain high explosives.³ On flax and grain demurrage begins to accrue day following placing of cars.⁴ Allows 72 hours at Butte and East Helena for unloading shipments of coal, coke, concentrates, lagging, lime, lime rock, lumber, ore, and stulls.⁵ Allows only 24 hours for unloading tank cars.⁶ Charges \$3 per day on all commodities in Arizona and California and on tank cars in New Mexico.

TABLE 11. List of States, showing how demurrage is regulated in each, provisions as to reciprocal demurrage, and variations from the uniform code on intrastate traffic.

[Uniform code: Free time, 48 hours; demurrage rate, \$1.]

State.	Regulated by—	Note.	Demurrage rate.	Free time.	Additional time.	Reciprocal demurrage.	
						Time allowed for furnishing cars.	Varying with— Penalty.
Alabama.....	Statute.....				72 hours allowed to unload brick, coal, coke, fertilizer, hay, lumber in closed cars, and the following commodities in bulk: Cotton seed, cottonseed hulls, cottonseed meal, grain, grain products, meal, and potatoes. 4 to 6 days allowed consignee 3 miles or more from depot. 24 hours additional time allowed when notice of arrival is given by mail.	2 to 10 days..... (1)	\$1.00
Arizona.....	Commission.....		\$8.00		(72 hours allowed to unload brick, coal, coke, fertilizer, hay, lumber in closed cars, and the following commodities in bulk: Cotton seed, cottonseed hulls, grain, grain products, meat, potatoes, and sand. Maximum of 5 days allowed shippers 5 miles or more from depot. 48 hours additional time allowed when notice of arrival is given by mail.	48 hours and up..... (1)	3.00
Arkansas.....	Statute.....					6 days.....	5.00
California.....	Commission.....		3.00			48 hours and up..... 5 days..... (1)	3.00 1.00
Colorado.....	Statute.....	(2, 3)					
Connecticut.....	do.....	(2, 3)					
Delaware.....	do.....	(2, 3)					
Florida.....	Commission.....			72 hrs.	96 hours allowed to unload brick, coal, dressed lumber in box cars, seed cotton, and the following commodities in bulk: Cabbage, cotton seed, cottonseed hulls, fertilizer material, and potatoes. 24 hours additional time allowed when notice of arrival is given by mail.	4 days..... 2 days only for fruit and vegetables.	2.00
Georgia.....	do.....				60 hours allowed to unload coal. 24 hours additional time allowed when notice of arrival is given by mail.	4 days.....	1.00
Idaho.....	do.....	(2, 3)					
Illinois.....	Commission.....	(6)					
Indiana.....	do.....	(1)					
Iowa.....	do.....	(1)					
Kansas.....	Statute.....	(1)			72 hours allowed to unload cars loaded in excess of 30 tons.	3 to 10 days..... (1)	5.00

¹ Number of cars ordered.² Roads apply uniform code on State traffic.³ Statute provides 4 days' free time.⁴ State has no railroad commission, nor does any statute cover.⁵ No demurrage rules prescribed, either by statute or orders of the commission.⁶ Commission has not yet exercised its authority to prescribe regulations.⁷ Commission has adopted the uniform code.

TABLE II.—List of States, showing how demurrage is regulated in each, provisions as to reciprocal demurrage, and variations from the uniform code on intrastate traffic—Continued.

State.	Regulated by—	Note.	De- mur- rage rate.	Free time.	Additional time.	Reciprocal demurrage.		
						Time allowed for furnishing cars.	Vary- ing with—	Pen- ing alty.
Kentucky.....	Commission.....	(1)						
Louisiana.....	do.....	(1)						
Maine.....	do.....	(2)						
Maryland.....	do.....	(1)						
Massachusetts.....	do.....	(2)						
Michigan.....	do.....				3 days allowed to unload charcoal, coal, coke, logs when teared from cars, lumber, and tanbark; 4 days to unload coal for coke ovens, sash doors, blinds inside finishing material, box material and mixed cars of dressed lumber or furniture loaded by various consignors; 5 days to unload lumber originating at lake ports and to load, weigh, and bill coal at mines; 15 days to unload coal for fueling transient vessels.			
Minnesota.....	Statute.....				(72 hours allowed to unload bituminous coal, bulk lime, fruit, lumber, and vegetables. 24 hours additional time allowed when notice of arrival is given by mail. 5 days allowed consignees more than 3 miles and less than 10 miles from station and 7 days for distances more than 10 miles. 72 hours allowed to unload cars loaded in excess of 30 tons. 72 hours allowed to unload cars loaded in excess of 30 tons. 72 hours allowed to unload coal, coke, concentrates, lagging, lime, lime rock, lumber, ore, silica rock, and stulls. 60 hours allowed to unload cars loaded in excess of 30 tons.	72 hours..... 48 hours only at terminal points.		\$1. 00
Mississippi.....	Commission.....					5 days.....		1. 00
Missouri.....	Statute.....					4 days.....		1. 00
Montana.....	Commission.....	(3)						
Nebraska.....	Statute.....			36 hrs.			Reciprocal features of the statute do not cover the furnishing of cars.	
Nevada.....	Commission.....	(4, 6)						
New Hampshire.....	do.....	(1)						
New Jersey.....	Statute.....			3 days				
New Mexico.....	do.....	(4, 10)						
New York.....	Statute.....	(1)						
North Carolina.....	Commission.....							
North Dakota.....	Statute.....							
Ohio.....	Commission.....	(1)						
Oklahoma.....	do.....				(72 hours allowed shippers located more than 5 miles from station. 72 hours allowed to unload cars containing more than 66,000 pounds.	72 hours.....		2. 00
Oregon.....	do.....					48 to 144 hours.....	(7)	1. 00
Pennsylvania.....	do.....	(8)	\$2. 00			5 to 20 days.....	(7)	2. 00
Rhode Island.....	do.....	(2)						

South Carolina.....	do.....			(72 hours allowed to unload bran, brick, coal, cottonseed, cottonseed hulls, cottonseed meal, crushed stone, dressed lumber in box cars, fertilizers, fertilizer material, flour, grain, hay, meal, mill feed, pyrites, and the following commodities in bulk: Apples, cabbage, and potatoes. Consignees 4 miles or more from depot allowed "sufficient time" "by the exercise of ordinary diligence" 24 hours additional time allowed when notice of arrival is given by mail. 24 hours additional time allowed when notice of arrival is given by mail.	4 days 3 days only for perishable.....	1.00
South Dakota.....	Statute.....				3 to 6 days.....	1.00
Tennessee.....	Commission.....	(7)				
Texas.....	do.....				3 to 8 days.....	.50
Utah.....	Statute.....	(4 6)	4 days		4 days.....	1.00
Vermont.....	Commission.....					
Virginia.....	do.....					
Washington.....	do.....				3 to 10 days..... For live stock and perishable cars must be furnished within a reasonable time.	1.00
West Virginia.....	Commission.....	(4 10) (1 11) (4 6)				(11)
Wisconsin.....						
Wyoming.....						

- 1 Commission has adopted the uniform code.
- 2 Without prescribing any regulations, commission has accepted roads' application of the uniform code.
- 3 Charge is \$2 per day after the first 5 days after the expiration of free time.
- 4 Roads apply uniform code on State traffic.
- 5 Uniform code approved and recommended, but not made compulsory by commission.
- 6 State has no railroad commission, nor does any statute cover
- 7 Number of cars ordered
- 8 Commission has not yet exercised its authority to prescribe regulations.
- 9 Place wanted and frequency of train service.
- 10 No demurrage rules prescribed, either by statute or orders of the commission.
- 11 Reciprocal features provided by a statute which is practically nonoperative.

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April 8, 1915.

(PROFESSIONAL PAPER.)

INSECTS AFFECTING VEGETABLE CROPS IN PORTO RICO.¹

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INTRODUCTION.

The following article can not be considered to include references to all the many insects which attack vegetable crops in Porto Rico. Undoubtedly there are many other insect species which are pests on plants, commonly classed as vegetables, that are grown on the island. Nevertheless it seems well to present the data available—data which have been obtained from references already published and from observations made by the writer since November, 1911, while a member of the staff of the experiment station of the Porto Rico Sugar Producers' Association. Especially does it seem timely to publish this paper because of the effort being made by the United States Department of Agriculture to obtain information upon the obnoxious insects liable to introduction into the United States, and because of the steps that are being taken to prevent them from being introduced. While it will be noted that many of the species mentioned in the following pages already occur in the United States, several are not known to be present on the mainland.

The determinations of the insects mentioned as having been observed by the writer have been made, with few exceptions, by specialists of the Bureau of Entomology, United States Department of Agriculture. The names of several of the wild host plants and of the fungi have been supplied by Mr. J. R. Johnston, pathologist of the experiment station of the Porto Rico Sugar Producers' Association.

It may be said in general that vegetables suffer severe injury in Porto Rico from insects. The vegetables grown are, for the most part, the same as those of the markets of the United States, although

¹ The observations on which this paper was founded were conducted by the author while a collaborator in Porto Rico.

NOTE.—This bulletin enumerates the more common insects attacking vegetable crops in Porto Rico; of interest to entomologists.

there are some with which the visitor from the North is not familiar. Among these may be mentioned a cucurbit, the "chayote" (*Sechium edule*); the "liren" (*Calathea allouya*), a canna-like plant with edible tubers; and the various members of the genera *Xanthosoma* *Colocasia*, known as "yautias," the latter known also as the "dasheen" in the southern United States.

The following figures, taken from the Summary of Transactions in the United States Customs District of Porto Rico, show the value of the vegetables brought into Porto Rico during the fiscal year ended June 30, 1912:

Vegetables, dried, canned, and pickled, imported by Porto Rico during fiscal year ended June 30, 1912.

Commodity.	Domestic merchandise from United States.		Merchandise imported from foreign countries.	
	Quantity.	Value.	Quantity.	Value.
	<i>Bushels.</i>		<i>Bushels.</i>	
Beans and dried peas.....	179,131	\$543,577	7,315	\$21,020
Onions.....	16,446	25,624	42,574	33,224
Potatoes.....	141,797	164,410	51,960	48,682
All others (canned).....		43,083		12,571
All others (including pickles and sauces).....		15,427		82,703
Total value.....		792,121		198,200

These figures indicate that the cultivation of vegetables could well be extended by those who have sufficient land at their disposal, and further study of the various vegetable insects, especially as regards control measures, would be of great importance in encouraging such cultivation.

THYSANOPTERA AND HEMIPTERA, OR SUCKING INSECTS.

THRIPS TABACI Lind.

This well-known species, the onion thrips, has been found attacking onions.

PEREGRINUS MAIDIS Ashm.

Where it occurs in abundance down among the unrolling leaves of corn, as it often does in Porto Rico, this "leafhopper" injures the leaves so that they have the appearance of having been scorched by fire. The presence of the "honeydew" which they secrete is responsible for the attendance of various ants and flies.

JASSIDÆ.

"*Agallia tenella* Ball," presumably *Eutettix tenella* Baker, was mentioned by Mr. Barrett in 1904¹ as having "injured beans and other small crops," and in the same year this species was mentioned on

¹ Barrett, O. W. Report of . . . entomologist and botanist. In Porto Rico Agr. Expt. Sta. Ann. Rpt. for 1903 [U. S. D. A. Office Expt. Stas. Rpt. 1903], p. 448, 1904.

page 84 of Bulletin No. 44 of the Division of Entomology, United States Department of Agriculture, as having been sent from Porto Rico by Mr. Barrett, with the statement that it damaged the leaves of beans, cowpeas, and other plants.

Mr. Barrett also mentioned *Empoasca mali* LeB., the currant leaf-hopper, in his 1903 report, above referred to (p. 448), as the "severest insect enemy of beans and cowpeas."

The writer has found *Empoasca mali* causing acute injury to garden beans, the leaves being badly curled and distorted.

APHIDIDÆ.

Though several species of aphides, or plant lice, attack vegetables, the well-known "melon aphis," *Aphis gossypii* Glov., is apparently the only one specifically recorded from the island. Mr. Barrett mentioned it in 1905,¹ and in 1906 Mr. Henricksen,² in discussing the cultivation of watermelons, stated that it "often infests the undersides of the leaves."

Aphis gossypii has been observed in abundance on cucumber, while other aphides have been found attacking corn, okra, and mustard. In his report for 1903 (p. 447) Mr. Barrett also stated that "a black aphid was found on a plant purchased as *Alocasia marshallii*, but believed to be a *Xanthosoma*" (yautia), and that "the malanga (*Colocasia antiquorum esculentum*) is occasionally attacked by an aphid which is usually parasitized by a whitish fungus and a hymenopter."

In the article in Bulletin No. 44 of the Division of Entomology the statement is made, on page 84, that, according to Mr. Barrett, an unknown species of *Aphis* seriously affects squashes.

Mr. Henricksen has mentioned, in the previously cited bulletin on vegetable growing (p. 38), an "eggplant aphis, a small light gray, mealy looking insect," which "appears on the underside of the leaves."

Aphis gossypii and other aphides found on okra are attacked by an internal parasite, perhaps *Aphidius testaceipes* Cress. A fungus, *Acrostalagmus albus* Preuss, attacks various species, and at least five species of ladybird beetles which feed upon aphides are present in Porto Rico. These are: *Cycloneda sanguinea* L., *Megilla innotata* Vauls., *Scymnus roseicollis* Muls., *Scymnus loewii* Muls., and *Hyperaspis apicalis* Muls. Syrphid flies are also common.

ALEYRODES sp.

Mr. Tower³ in 1908 stated that "a white fly (*Aleyrodes* sp.) appeared in great numbers on the peppers and tomatoes" at the experiment station at Mayaguez, P. R. He further mentions that "there

¹ Barrett, O. W. Report of . . . entomologist and botanist. In Porto Rico Agr. Expt. Sta. for 1904 [U. S. D. A. Office Expt. Stas. Rpt. 1904], p. 306, 1905.

² Henricksen, H. C. Vegetable growing in Porto Rico. Porto Rico Agr. Expt. Sta. Bul. 7, p. 58, 1906.

³ Tower, W. V. Report of the Entomologist and Plant Pathologist. Porto Rico Agr. Expt. Sta. Ann. Rpt. for 1907, p. 36.

appears to be a great number of parasites." Two species of syrphid flies were reared and a parasitic fungus was observed.

COCCIDÆ.

The following scale insects have been taken on truck crops: *Saissetia hemisphærica* Targ. (Pl. I, fig. 1) and *Hemichionaspis minor* Mask. on eggplant, and *Diaspis pentagona* Targ. on okra and pepper.

A mealybug has been found at the roots of celery and corn which has been determined as *Pseudococcus* sp. near *citri* Risso. It was abundant on the crowns of plants growing in rather dry soil, and was in many cases attended by the "fire ant," *Solenopsis geminata* Fab.

SPARTOCERA BATATAS Fab.

Adults (Pl. I, fig. 2) and nymphs of *Spartocera batatas* have been observed in great abundance on sweet potato, their beaks embedded in the stalks and leaf petioles of the plants.

CORYTHUCA GOSSYPH Fab.

The tingitid *Corythuca gossypii*, which breeds on the undersides of yautia leaves, also occurs in the same situation on the sword bean (*Canavalia ensiformis*) and the castor bean (*Ricinus communis*).

PHTHIA PICTA Drury.

This coreid bug (Pl. I, fig. 3) attacks tomato and *Solanum nigrum* var. *americanum* at Rio Piedras, and both adults and nymphs have been observed by the writer inserting their beaks into the fruit of both host plants.

CORYTHAICA MONACHA Stål.

Nymphs and adults of *Corythaica monacha* have been observed to be so abundant on the undersides of the leaves of eggplant that all the foliage withered, turned brown, and fell from the plant. Although this was an unusual instance, this tingitid is an important enemy of the eggplant. Plants of a common solanaceous weed, *Solanum torvum*, are also often attacked.

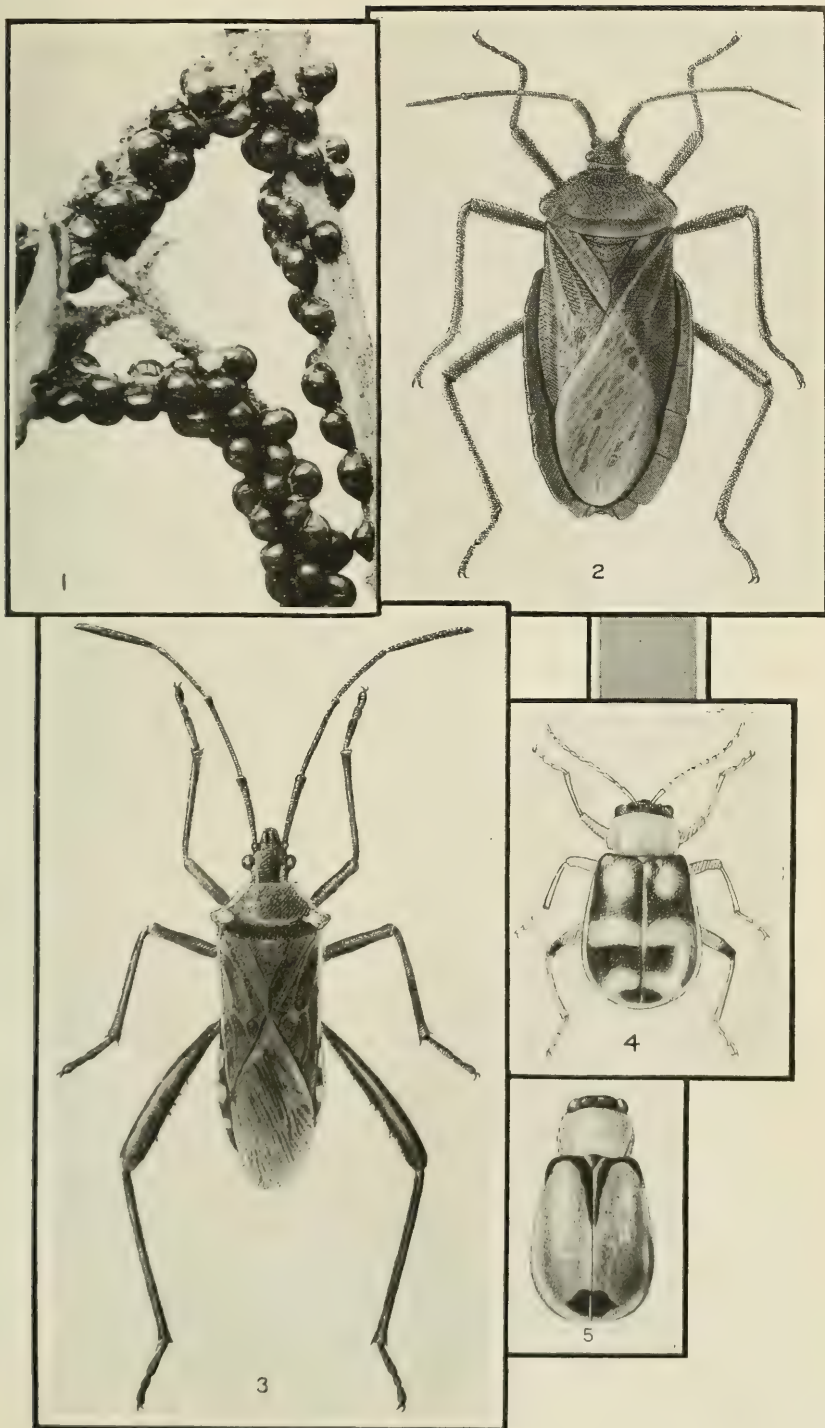
ORTHOPTERA.

SCAPTERISCUS DIDACTYLUS Latr.

Probably the most notorious of Porto Rico insects is the "mole cricket," or "changa" (*Scapteriscus didactylus*), which injures many vegetables by cutting off the plants at or just below the surface of the soil.

In the most complete article on this species so far published in English¹ it is stated that "among the small crops the tomato, egg-

¹ Barrett, O. W. The changa or mole cricket (*Scapteriscus didactylus* Latr.) in Porto Rico. Porto Rico Agr. Exp. Sta. Bul. 2, 19 p., 1 fig., 1902.



INSECT ENEMIES OF VEGETABLE CROPS IN PORTO RICO.

FIG. 1.—The hemispherical scale (*Saissetia hemisphaerica*) on eggplant. FIG. 2.—*Spartocera habitus*: Adult. Greatly enlarged. FIG. 3.—*Phthia picta*: Adult male. Much enlarged. FIG. 4.—*Cerotoma denticornis*: Beetle. Enlarged. FIG. 5.—*Cerotoma denticornis*: Pale variety. Enlarged. (Original.)



FIG. 1.—*PIERIS MONUSTE*: MALE BUTTERFLY. MUCH ENLARGED. (ORIGINAL.)



FIG. 2.—*NACOLEIA INDICATA*: MALE MOTH. ENLARGED. (ORIGINAL.)

LEPIDOPTERA INJURIOUS TO VEGETABLES IN PORTO RICO.

plant, turnip, and cabbage are most affected," and that the water-melon, bean, sweet potato, and yautia are seldom or never attacked.

COLEOPTERA.

DIABROTICA BIVITTATA Fab. and D. INNUBA Fab.

These two chrysomelid beetles occur in abundance on cucumber, squash, and melon, especially on the flowers. They quite closely resemble *Diabrotica vittata* Fab. in appearance and habits, and those authors who have referred to *vittata* as being present on the island have apparently failed to differentiate between the species.

DIABROTICA GRAMINEA Bal.

This chrysomelid beetle is very common in Porto Rico. Mr. Van Dine has reported the adults as feeding on the leaves of sugar cane to a slight extent.¹

The beetles are bluish-green in color and about one-fourth of an inch in length. So far as the writer has observed, the injury is most severe on corn and okra, which are, in fact, the only two plants of this group upon which the writer is certain that they feed, although they have been observed feeding on the flowers of cowpeas, the fruit of *Solanum nigrum* var. *americanum*, and the foliage of "jobo" (*Spondias lutea*) and "bledo" (*Amaranthus spinosus*).

The injury to corn is apparently confined to the silk of the ear and the blossom spike. On these parts of the plant the beetles congregate in great numbers, and the results of their feeding are very apparent, especially on that portion of the silk which, ordinarily projecting from the tip of the husk, is completely destroyed. On okra they feed upon the blossoms and the young leaves.

An assassin bug, *Zelus rubidus* Stål., has been taken with a beetle of this species impaled upon its beak.

CEROTOMA DENTICORNIS Oliv.

In appearance this beetle resembles the bean leaf-bettle (*Cerotoma trifurcata* Forst.), which also occurs in the United States, and, as is the case with the latter species, there is a marked difference in the markings on the wing-covers. This difference is shown in figures 4 and 5 of Plate I.

Adults of *Cerotoma denticornis* have been found feeding upon garden beans and cowpeas, plants which have been reported on the mainland as food plants of *trifurcata*. The habits of the two species are quite similar. Mr. Barrett, in his 1903 report (p. 448), mentioned *denticornis* as being common.

¹ Van Dine, D. L. Report of the Entomologist. Sugar Producers' Association of Porto Rico. Ann. Rpt. 3, p. 34, 1913.

EPITRIX CUCUMERIS Harr.

Flea-beetles have been taken on eggplant and tomato, which agree with those taken in company with *Epitrix parvula* Melsh. on a weed (*Physalis* sp.). Those taken on the latter plant were said by Mr. E. A. Schwarz to be "properly not different from the U. S. cucumber flea-beetle, *Epitrix cucumeris*." On the eggplant the beetles were causing the familiar "flea-beetle injury" to the leaves.

CHÆTOCNEMA APRICARIA Suffr.

This insect injures sweet potato leaves in much the same manner as does *Chætocnema confinis* Lec. in the United States, searing them with short, continuous, curved lines. The beetle is of a dark metallic-green color and has been observed in abundance at certain seasons on a common weed, related to the sweet potato.

COPTOCYCLA SIGNIFERA Herbst.

An adult of this "tortoise beetle" has been taken on the leaves of sweet potato. In the United States the species is known as an enemy of this crop.

CRYPTORHYNCHUS BATATÆ Waterh.

The writer is able to record this enemy of the sweet potato through the kindness of Mr. R. H. Van Zwaluwenburg, Entomologist of the Porto Rico Agricultural Experiment Station. Mr. Van Zwaluwenburg has found it attacking sweet potato tubers at Mayaguez. The species has been mentioned as an enemy of the sweet potato in the Lesser Antilles, where it seems to be a more important pest than *Cylas formicarius*.

CYCLAS FORMICARIUS Oliv.

The "sweet-potato root-borer" is present in Porto Rico, it having been observed working in the tuberous root of a wild convolvulaceous plant.

LEPIDOPTERA.

PIERIS MONUSTE L.

The "southern cabbage worm" was mentioned by Mr. Tower in his 1907 report (pp. 35 and 36) as feeding on cabbage, radish, turnip, kale, and mustard. The male butterfly is shown in Plate II, figure 1.

The larvæ have also been found feeding on horseradish and an uncultivated plant, *Cleome spinosa*, of the family Capparidaceæ. This weed is evidently an important wild food plant of *P. monuste* in Porto Rico and is commonly found, especially on the lower lands, near the rivers. Prof. Ignatius Urban gives it the local Spanish common name of "jasmin del rio" in his *Flora Portoricensis*.

EUDAMUS PROTEUS L.

This hesperid, the so-called "bean leaf-roller," feeds upon garden beans, cowpeas, and a related weed, *Phaseolus lathyroides*.

Eggs that probably belonged to this species, found on the leaves of the last-mentioned plant, were parasitized by *Trichogramma minutum* Riley.

PHLEGETHONTIUS SEXTA Joh.

Mr. Barrett reported this species, under the name of *Protoparce carolina*, in his 1903 report (p. 448) as occurring commonly on tomato and tobacco throughout the island, and made the interesting note that the larvæ were usually killed by a thrust of a knife made from a "maya" (*Bromelia pinguin*) leaf. The larva also feeds upon the common "berengena cimarrona" (*Solanum torvum*), and Mr. Tower has stated in his 1907 report (p. 36) that the parasite *Telenomus monilicornis* held in check the "tobacco hornworm" (probably this species), eggs of which were found on tomato and pepper.

PHLEGETHONTIUS CONVULVULI L.

Adults of this species, which is known elsewhere as a sweet potato pest, have been collected at Rio Piedras, P. R.

LAPHYGMA FRUGIPERDA S. & A.

Although corn and onions are the only vegetables so far observed to be attacked by the larvæ of *Laphygma frugiperda*, or "grass worm," the list of such plants upon which they feed is undoubtedly much larger.

In addition to the enemies previously recorded by the writer,¹ namely, the three tachinid flies, *Frontina archippivora* Will., *Gonia crassicornis* Fab., and *Archytas piliventris* V. d W., the larvæ are attacked by two fungi, *Botrytis rileyi* Farlon and *Empusa* sp., and by an assassin bug, *Zelus rubidus* Stål. An interesting parasite, *Chelonus insularis* Cress. (?), the egg of which is laid in the *Laphygma* egg, the parasite issuing from and killing the host larva when the latter is about one-half inch in length, has also been observed.

A carabid beetle, *Calosoma alternans* Fab., is predaceous upon the larvæ, and another carabid, *Cymindis marginalis* Dej., probably has the same habit.

HELIOTHIS OBSOLETA Fab.

The corn ear-worm attacks corn in Porto Rico and is to be considered an important pest to this crop. Mr. Barrett mentioned it in his 1903 report (pp. 443 and 444).

¹ Some notes on *Laphygma frugiperda* S. & A. in Porto Rico. Jour. Econ. Ent., v. 6, no. 2, p. 235, April, 1913.

OTHER NOCTUIDÆ.

Three other noctuid moths, that have been reared from larvæ, belong to the species known to injure truck crops in the United States. *Xylomyges eridania* Cram., the larvæ of which occurred on *Amaranthus* sp., has been mentioned by Messrs. Chittenden and Russell under the name of *Prodenia eridania* Cram.¹ as attacking Irish potatoes, egg-plant, pepper, okra, and sweet potato in Florida, and they give, on another's authority, beets, cabbage, and carrots as food plants.

Prodenia ornithogalli Guen., the cotton cutworm, reared from larvæ found feeding on a weed of the family Convolvulaceæ, is stated by Dr. Chittenden to be an enemy of several vegetable crops.²

The larvæ of *Feltia annexa* Treits., which species has been reared from larvæ found in an area where "grass worms" (*Laphygma frugiperda* S. & A. and *Remigia repanda* Fab.) were abundant, is known as a cutworm on the mainland.

DIAPHANIA HYALINATA L.

Cucumbers and squashes are frequently severely attacked by the larvæ of this species, the melon caterpillar. Mr. Barrett mentioned the species in his 1903 report (p. 448):

PACHYZANCLA BIPUNCTALIS Fab.

The "southern beet webworm" has been found feeding on garden beans, sword bean (*Canavalia ensiformis*), and weeds belonging to the genus *Amaranthus*. Upon the garden bean and *Amaranthus* it was feeding on the leaves, which it webs together, forming for itself a shelter, as is commonly done by pyralid larvæ. The leaf or leaves of which the shelter is formed are skeletonized and the pupæ are sometimes found in the shelters, but more often in earthen cells just below the soil surface. The larvæ found on sword bean were feeding within the green pods.

Exorista pyste Walk., a tachinid parasite of the larvæ, has been observed.

In connection with *Pachyzancla bipunctalis* it may be mentioned that another pyralid, *Hymenia* (*Zinckenia*) *fascialis* Cramer, occurs in Porto Rico. It has been observed under conditions that would indicate that the larvæ feed upon *Amaranthus* spp. Mr. H. O. Marsh has studied this species in the Hawaiian Islands, and in Bulletin 109, Part I, of the Bureau of Entomology, states that various beets and several species of *Amaranthus* are among the plants which suffer from its attack there.

¹ Chittenden, F. H., and Russell, H. M. The semitropical army worm. (*Prodenia eridania* Cram.). U. S. D. A., Bur. Ent., Bul. 66, pt. 5, p. 53-70, figs. 8-11, Jan. 28, 1909.

² Chittenden, F. H. Some insects injurious to the violet, rose, and other ornamental plants. U. S. D. A., Div. Ent., new ser. Bul. 27, rev., p. 64, 68, 69, 70, 1901.

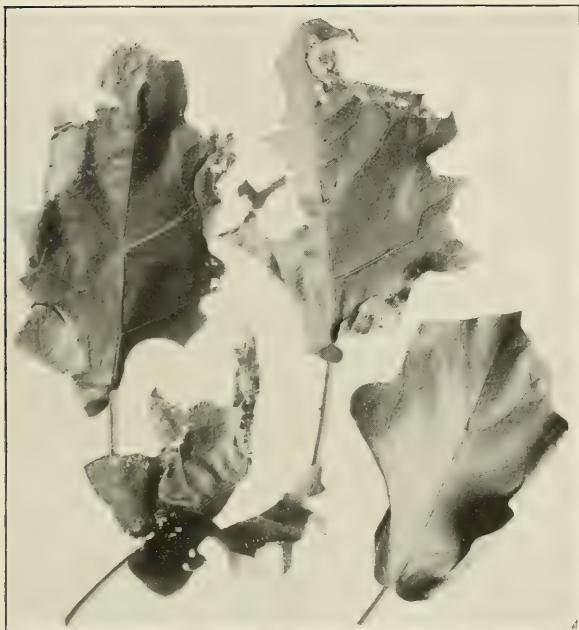


FIG. 1.—WORK OF THE LARVA OF *PACHYZANCLA PERIUSALIS* ON *SOLANUM TORVUM*. (ORIGINAL.)



FIG. 2.—*PILOCROCIS TRIPUNCTATA*: MOTH. ENLARGED. (ORIGINAL.)

LEPIDOPTERA INJURIOUS TO VEGETABLES IN PORTO RICO.



MUSTARD LEAF SHOWING INJURY BY THE DIAMOND-BACK
MOTH (*PLUTELLA MACULIPENNIS*). (ORIGINAL.)

PACHYZANCLA PERIUSALIS Walk.

Larvæ of this pyralid moth feed upon the leaves of eggplant and *Solanum torvum*. The young larvæ live at first as miners in the leaves, but later web the leaves together. (See Pl. III, fig. 1.) The shelter is usually formed near the edge of the leaf, a portion of which is folded in toward the midvein and held in place by silken threads. Sometimes, however, parts of two or more leaves form the shelter. The larvæ feed from within these areas and are often common on both plants mentioned as hosts.

The moth has a wing expanse of three-fourths to seven-eighths of an inch and is gray in color. The wings are glistening and marked above with three darker, wavy, transverse lines, the two inner ones extending across both wings, while the outer one extends from the costal margin to a point near the middle of the front wing.

NACOLEIA INDICATA Fab.

The larva feeds upon the leaves of garden bean, webbing together parts of the same leaf or separate leaves. It also occurs on cowpea.

The adult, Plate II, figure 2, is golden yellow, the wings marked with black along the outer margin, and above with three black wavy lines extending across them, much as do the dark lines on the wings of *Pachyzancla periusalis*.

PILOCROCIS TRIPUNCTATA Fab.

Sweet-potato leaves have been found webbed together and injured by the larvæ.

The moth, shown in Plate III, figure 2, is light yellow, the wings being marked with black and brown, and having an expanse of about an inch.

PLUTELLA MACULIPENNIS Curtis.

Larvæ of the "diamond-back moth" are at times very abundant on and destructive to the leaves of cabbage. Mr. Barrett mentioned the species in his 1903 report (p. 448) and Mr. Tower, in his 1907 report (p. 35), listed cabbage, kale, mustard, and turnips as food plants, briefly summarized its life history, made note of a parasite, and mentioned remedies to be applied. A mustard leaf which has been severely injured by the larvæ is shown in Plate IV.

HYMENOPTERA.

SOLENOPSIS GEMINATA Fab.

The "fire ant," or "hormiga brava," has been found injuring okra plants by cutting away parts of the flowers and portions of the younger growth.

It is often stated in Porto Rico that ants destroy certain vegetable seeds after they have been planted in the soil. The writer has been told on good authority that ants, which from the description were apparently the "hormiga loca" or "crazy ant," *Prenolepis longicornis* Latr., were seen to dig small holes along the rows in a propagating box in which lettuce had been planted, remove the seeds, and carry them away.

DIPTERA.

AGROMYZA PARVICORNIS Loew.

The "corn-leaf blotch miner," which has been recently made the subject of a paper¹ by Mr. W. J. Phillips, is present in Porto Rico, adults having been reared from larvæ found working in leaves of corn at Rio Piedras.

SUMMARY.

The following summary, arranged alphabetically according to host plants, indicates the insects known to attack the various vegetable crops grown in Porto Rico. The "changa" (*Scapteriscus didactylus* Latr.) is credited in this list as injuring only those plants which, according to Mr. Barrett, are most affected, though in reality the list of plants attacked by it is not so limited.

Beans:

- Eutellix tenella* Baker. (?)
- Eudamus proteus* L.
- Empoasca mali* Le B.
- Cerotoma denticornis* Oliv.
- Nacoleia indicata* Fab.

Beets:

- Pachyzancla bipunctalis* Fab.

Cabbage:

- Scapteriscus didactylus* Latr.
- Plutella maculipennis* Curtis.
- Pieris monuste* L.

Celery:

- Pseudococcus* sp. near *citri* Risso.

Corn:

- Peregrinus maidis* Ashm.
- Pseudococcus* sp. near *citri* Risso.
- Diabrotica graminea* Baly.
- Laphygma frugiperda* S. & A.
- Heliothis obsoleta* Fab.
- Agromyza parvicornis* Loew.

Cucumber:

- Aphis gossypii* Glov.
- Diabrotica bivittata* Fab.

Cucumber—Continued.

- Diabrotica innuba* Fab.
- Diaphania hyalinata* L.

Eggplant:

- Saissetia hemisphaerica* Targ.
- Hemichionaspis minor* Mask.
- Corythaica monacha* Stål.
- Scapteriscus didactylus* Latr.
- Epitrix cucumeris* Harris (?).
- Pachyzancla periusalis* Walk.

Horse-radish:

- Pieris monuste* L.

Kale:

- Pieris monuste* L.
- Plutella maculipennis* Curtis.

Melon:

- Aphis gossypii* Glov.
- Diabrotica bivittata* Fab.
- Diabrotica innuba* Fab.

Mustard:

- Pieris monuste* L.
- Plutella maculipennis* Curtis.

Okra:

- Diaspis pentagona* Targ.
- Diabrotica graminea* Baly.
- Solenopsis geminata* Fab.

¹ Phillips, W. J. Corn-leaf blotch miner [*Agromyza parvicornis* Loew]. In U. S. Jour. Agr. Research, v. 2, no. 1, p. 15-31, 6 figs., 5. pl., Apr. 15, 1914.

Onion:

Thrips tabaci Lind.*Laphygma frugiperda* S. & A.

Pepper:

Aleyrodes sp.*Diaspis pentagona* Targ.

Radish:

Pieris monuste L.

Squash:

Diabrotica bivittata Fab.*Diabrotica innuba* Fab.*Diaphania hyalinata* L.

Sweet potato:

Spartocera batatas Fab.*Chætocnema apricaria* Suffr.*Pilocrocis tripunctata* Fab.*Cryptorhynchus batatæ* Waterh.

Sweet potato—Continued.

Other insects, known as sweet-potato pests in the United States, are also present, namely—

Coptocycla signifera Herbst.*Cylas formicarius* Oliv.*Phlegethontius convolvuli* L.

Tomato:

Scapteriscus didactylus Latr.*Phlegethontius sexta* Joh.*Aleyrodes* sp.

Turnip:

Scapteriscus didactylus Latr.*Pieris monuste* L.*Plutella maculipennis* Curtis.

Yautia:

Corythuca gossypii Fab.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 193

Contribution from the Office of Experiment Stations
A. C. TRUE, Director

Washington, D. C.

PROFESSIONAL PAPER

April 30, 1915

THE DRAINAGE OF
JEFFERSON COUNTY, TEXAS

By

H. A. KIPP, A. G. HALL, and S. W. FRESCOLN
Drainage Engineers

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INTRODUCTION.

The drainage of Jefferson County, like the drainage of all other counties along the Texas Gulf coast, has been generally recognized in recent years as one of the most important steps in the agricultural development and settlement of this comparatively new country. Several attempts have been made to organize drainage districts within the county under the Texas drainage law and to start actual construction of some drainage canals to relieve the land of the surplus water, but up to the present time construction has been carried out in only one district. Outside of that district few canals have been constructed, and the conditions throughout the county generally have not been improved.

In January, 1912, the Chamber of Commerce of Beaumont requested the assistance of Drainage Investigations, Office of Experiment Stations, United States Department of Agriculture, in making drainage plans and estimates for Jefferson County. On February 15 the county commissioners' court adopted resolutions agreeing that if Drainage Investigations would make the necessary survey and prepare a drainage plan the county would bear one-half the cost. The survey and

NOTE.—This report is intended especially for engineers, drainage district officials, and present and prospective owners of land near the Gulf of Mexico, particularly in Texas and Louisiana. The run-off formula and discussion will interest all engineers concerned with land drainage.

plan were roughly estimated to cost \$15,000. Following a preliminary investigation and report, the cooperation offered by the county commissioners was accepted and the survey was authorized. Head-

quarters for the survey were established at Beaumont; field work was begun April 8 and completed December 1, 1912.

GENERAL DESCRIPTION OF JEFFERSON COUNTY.

Jefferson County is wholly within the Coastal Plain of south-east Texas, reaching from the Gulf of Mexico on the south to Pine Island Bayou on the north and separated from Louisiana by Sabine Lake and Sabine Pass. (See fig. 1.) The area is approximately 956 square miles, or 612,000 acres, and the population about 40,000. The principal cities of the county are Beaumont and Port Arthur. The proposed Intercoastal Canal to connect the Neches River and the

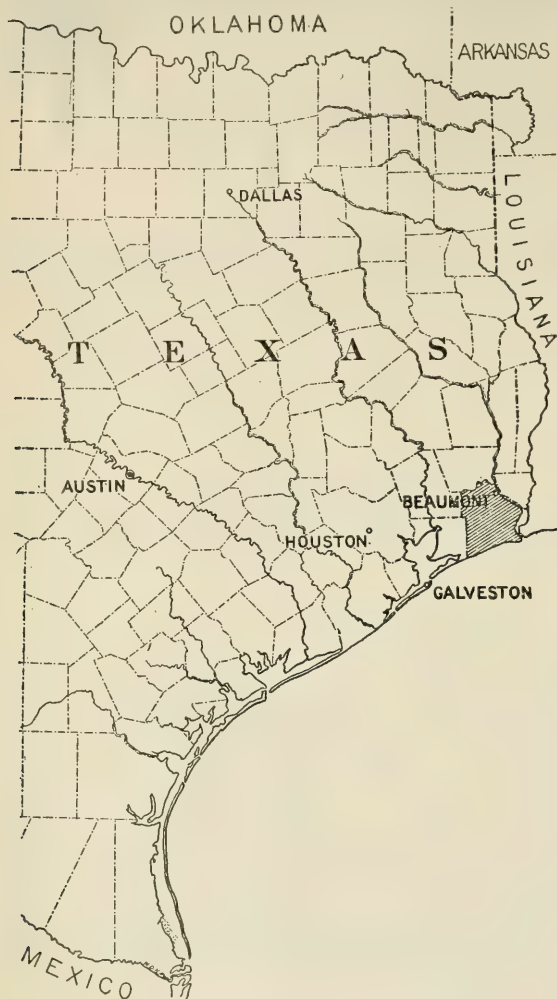


FIG. 1.—Map showing location of Jefferson County in Texas.

Sabine-Neches Canal with Galveston Bay will traverse the southern part of the county, and Taylors Bayou is used extensively for transportation by the farmers in the central part. About 100 miles of shell highways and about 500 miles of graded earth roads traverse practically all parts of the county except the great salt marshes bordering on the Gulf.

The principal agricultural products of the county are rice and garden truck, but quantities of cotton, corn, and fruits are raised. In the northern half of the county is a very extensive system of canals

for rice irrigation, about 500 miles of mains and laterals being now in use. The live-stock industry is extensive, particularly in the southern part where many thousands of acres are given over to grazing. The turpentine industry along Pine Island Bayou is a source of considerable activity and profit. The country between Beaumont and Port Arthur is studded with huge oil tanks and oil pumping stations.

TOPOGRAPHY.

The surface of Jefferson County is typical of the Coastal Plain, being generally flat and level with few physical features especially marked. The land was built from deposits brought from higher elevations by the streams, and later exposed when the waters of the Gulf receded. Figure 2 (in pocket at end of bulletin) shows the principal water courses, the watershed lines, and the areas drained by the streams.

The highest elevation in the county is 46 feet above sea level, in the northwest part near Nome. From the northern part of the county the ground slopes gradually southward to a great level tract of salt marsh scarcely 1 foot above sea level bordering the Gulf, Sabine Lake, and the lower reaches of the Neches River. To the eye the whole county seems perfectly level, but instrumental surveys show that the surface, excepting the low flat marshes, is undulating and has a considerable slope. This fact is in a measure shown by the locations of the main irrigation canals, which usually follow the higher contours. The only marked slopes in the county, besides the bluff bordering the Neches River marsh and the sloping banks of Pine Island Bayou, are Spindletop oil field south of Beaumont and Big Hill 7 miles south of Hamshire. Spindletop is 10 to 12 feet higher than the ground one-half mile west of the center of the oil field, and Big Hill has an elevation of about 20 feet above the surrounding country. There are a few places along Taylors Bayou near La Belle where the banks are high.

The entire northwestern portion of the county is peculiarly devoid of well-defined streams or drainage channels. Water stands on the ground for weeks at a time after every rain, and sometimes the land remains under water throughout an entire season. Under present conditions evaporation is a greater agent of natural drainage in this section than percolation or flow to any natural outlet. The west-central part of the county is also lacking in large natural channels which would aid drainage, and there are only a very few small streams like Spindletop Gully and the upper end of Big Hill Bayou which carry the overflow waters down to the salt marsh adjacent to the coast. Several large bodies of level inland or fresh-water marshes occur in various parts of the county where water stands the greater part of the year.

A natural sand levee 4 to 6 feet high extends practically the full length of the Gulf shore line. This levee was formed by wind and wave action and protects the salt marsh adjacent to the Gulf from ordinary storm tides. Owing to a gap in the levee, however, protection is not afforded against the extreme storm tides which occur at irregular intervals of one to ten years.

WATERCOURSES.

The Neches River is a winding stream 20 to 40 feet deep and ranging from 400 to 800 feet wide. The banks are generally low and flat, being scarcely 1 foot above the ordinary water level. Marshes 1 to 2 miles wide separate the high land from the river except at Colliers Ferry, Beaumont, the Port Arthur Rice & Irrigation Co.'s pumping plant, and Port Neches. The total length of bluff line fronting directly on the river is about 3 miles. The river bluff, which extends from the Neches Canal Co.'s pumping plant at Voth to the mouth of the river, is higher than the land back from the stream, and practically all drainage is away from the river. A few small gullies break the bluff line and provide drainage for adjacent ground, but very little drainage from Jefferson County enters the Neches except what comes through Pine Island Bayou. A strip of land bordering that bayou along its entire length in the county and averaging about 3 miles wide slopes rather abruptly toward the stream and is drained by that route; the remainder of the county, except a very small portion in the southwestern corner and the great salt marsh bordering on the Gulf, is drained into Sabine Lake by way of Taylors Bayou and its tributaries.

Taylors Bayou is the principal water course within the county, rising in a large fresh-water marsh north of Hamshire and emptying into Sabine Lake. It is very crooked, and is 10 to 15 feet deep and 200 to 400 feet wide along the lower portion. Tide water extends up the bayou to a point near the center of the county. Upstream from that point the banks of the bayou are covered with timber and heavy underbrush. The channel as a rule is badly clogged with logs, driftwood, and débris, which together with the bends in the stream, greatly impede the natural drainage, although improvements in drainage district No. 3 have greatly relieved the upper reaches. The principal tributaries of Taylors Bayou are the North Fork, Hillebrant Bayou, Mayhaw Bayou, and Rodair Bayou. The North Fork is similar in all respects to the upper end of the main channel. Hillebrant Bayou is a tortuous stream flowing through a strip of heavily timbered land. It is badly obstructed by fallen timber, driftwood and brush growing in the channel, except in the lower reaches where the channel is wide, deep, and open. The western part of the city of Beaumont suffers greatly from the frequent overflows. The principal tributary of

Hillebrant Bayou is Bayou Din, similar in all respects to the upper end of Hillebrant Bayou. Above the Gulf & Interstate Railway crossing the channel is not well defined, and below the railroad the stream banks are overgrown with timber and brush. The two other important tributaries, Piviot Bayou and Willow Marsh, provide much better drainage to the adjacent lands than does Bayou Din. They are less winding, and they flow through open country, therefore the channels are less obstructed by logs and driftwood than are the streams flowing through the woods.

The great salt marsh is traversed by Salt Bayou which heads in Star Lake about midway between Sabine Pass and the west county line, leads northeasterly through a number of shallow lakes and parallel to the Gulf shore, then turns north into Taylors Bayou near West Port Arthur. It is the outlet for Kieth Lakes, Salt Lake, Knights Lake, Fence Lake, and some others. Big Hill Bayou is a much smaller watercourse draining an area between Salt Bayou and Taylors Bayou. Mud Bayou, in the extreme southwest corner of the county, flows through Chambers County into Galveston Bay and is the only stream not having its outlet in Jefferson County. Alligator Bayou drains a considerable area of marsh and of higher lands west and north of Port Arthur. In several places it spreads over the marshes without any defined channel, but in many respects is similar to Salt Bayou. These bodies of water are at tide level and are subject to all the tidal changes of the Gulf, the extent to which they are affected depending upon the height and duration of the tides. They are of little value as drainage channels because they have practically no fall and are very shallow and crooked.

CLIMATE.

The region is characterized by long warm summers and short mild winters. Records of the United States Weather Bureau indicate that the summer temperatures seldom exceed 100° F., and as a rule the heat is tempered by cool breezes from the Gulf, for the prevailing winds are southerly. The average annual temperature at Beaumont is about 68°, the average monthly ranging from about 52° in February to 82° in July. Extreme variations from these averages sometimes occur, heavy killing frosts in winter and very hot weather for short periods in summer being not at all uncommon. In winter especially, sudden drops of temperature are caused by cold north winds commonly known as "northers"; the cold spells seldom last more than a few days at a time, however.

The mean annual precipitation at Beaumont during the past 20 years was 46.3 inches, and at Houston 48 inches. For ordinary crops the rainfall is sufficient in amount and evenly enough distributed, but rice culture makes irrigation necessary.

SOILS.

In connection with the drainage survey a number of soil borings were made in all parts of Jefferson County to depths of 10 to 15 feet, to ascertain whether any unusual difficulties would be encountered in the construction of ditches and levees or in draining the land by tiling. Several distinct types of soils were found, the predominating surface soils being fine sandy loams, loams, clay loams, silt deposits, and muck, all underlain by a deep stratum of clay. Limited areas of fine sand were also found at the surface in certain parts of the county.

The most common type of surface soil is the fine sandy loam, averaging 12 to 14 inches deep; this was found upon practically all the higher land which may be drained by gravity. The loam soils are mostly found in the great flat areas or fresh-water marshes in the interior of the county. The marshes bordering on the Neches River are composed entirely of alluvial soil, and the open marshes south of Beaumont are largely muck with a high percentage of silt. Parts of these marshes are so soft it is nearly impossible to walk across them. The great marsh in the southern part of the county is composed principally of muck formed by decaying marsh grass, underlain by silt. Practically every boring encountered clay between the 2-foot and 10-foot depths; below 10 feet the clays contained much sand, and some pockets of quicksand were found at 10 to 13 feet.

So far as the construction of drainage works is concerned, no particularly unfavorable soil conditions were found on the upland portion of the county. The underlying clays of that region are quite impervious and prevent the downward percolation of water, and it is this fact that makes the level prairies so valuable for growing rice. However, where any other crops are grown it will be found advantageous to lay tile to remove the surplus water from the soil. Tiling has not been tried to any extent in Jefferson County, principally because rice is the principal crop and because there are at present no outlets for underdrains, but there is no doubt that this kind of drainage will work successfully in this soil. The marsh soils may cause considerable trouble during construction if caution is not exercised in handling the soft materials. The removal of surplus water from the ground will tend to solidify the marsh soil, and cultivation will assist in making it firm. Sugar cane, rice, corn, forage, and truck have been raised in Louisiana on reclaimed marsh lands that appear to be similar to the marshes of Jefferson County, Tex.

NATURAL VEGETATION.

The natural vegetation on the great level prairies is ordinarily prairie grass and sedge. The salt marshes support a heavy growth of salt or wire grass, and in some places, particularly along the bayous

and low spots, dense growths of rushes and reeds are found. Both the prairies and the marshes are used for grazing purposes. Approximately nine-tenths of the county is in open prairie or marsh, the remainder being covered with the native growth of timber and underbrush. Lawhorns Woods, located north and west of Fannett, and Pine Island Bayou Woods are the largest timber areas, but several other patches are found along the upper reaches of Taylors Bayou, on Hillebrant Bayou and Bayou Din, and along the Neches River bluff. Pine is the predominating tree, but water oak, live oak, and post oak are also plentiful. The undergrowth is thick and consists of palmetto and other semitropical vegetation, green briars, and blackberry bushes.

PRESENT DRAINAGE SITUATION.

As a whole, the county has very poor natural drainage, as has been indicated. In only a few favored spots is the ground well drained, and practically every farm should have artificial drainage either by open ditches or by tile. Farmers in all parts of the county have suffered severe losses, and the rice farmers are particularly in need of some means of draining their fields during planting and harvesting seasons. Practically the entire southern half of the county is very wet and marshy at all times, and until some system of thorough drainage is installed the land can not be cultivated at all.

DRAINAGE DISTRICTS ORGANIZED.

Drainage district No. 3, comprising about 47,000 acres south of Hamshire, has had surveys and plans made, and construction has been completed. Two other attempts to organize drainage districts have been made, but owing to lack of cooperation among the landowners and to the inadequacy of the law the organizations have not been perfected and no construction work has been done. Some years ago several drainage ditches were constructed south of China, but they have not been well maintained and will need to be reconstructed before they will fulfill the purpose for which they were intended. They have no outlets and are neither large enough nor deep enough.

THE SURVEY.

Carefully checked base levels were first run on all the railroads from Beaumont to the boundaries of the county. Bench marks were established at intervals of 1 mile or less on railroad mileposts or other convenient objects. All elevations were referred to sea-level datum as established by War Department engineers. Lines of levels were run across the county at intervals of 1 mile or less, approximately east and west or north and south, generally with the slope of the ground. Roads and fences were often followed for convenience. Tie lines were run perpendicularly to the cross lines in order

to determine additional elevations and to check the work. Very little time was given to locating property corners, and as most of the land is divided into irregular tracts according to original surveys, the cross levels were all located with respect to mileposts or other objects of known location along the railroads. The south end of the county is subdivided into square miles which are numbered consecutively, but a great many of the corners are now obscured and the level lines were located only approximately. All the streams were meandered with compass and stadia, and levels were carried on many of the meanders. A sufficient number of channel cross-sections were taken to determine the sizes and capacities of the streams. For determining the area drained into Jefferson County from the west, lines of levels were projected west from the county line at intervals of 2 miles and were carried beyond the divide between the Trinity and Neches Rivers. Numerous bench marks were established in all parts of the county, the locations, descriptions, and elevations of which may be obtained upon request to the Chief of Drainage Investigations, United States Department of Agriculture.

A tract of about 70 square miles lying east of the Texas & New Orleans Railroad (Sabine branch) was omitted from this survey because the owners furnished a contour map of the tract, which was adopted as correct after being checked by several lines of cross levels. A number of land maps furnished by the county surveyor and right-of-way maps supplied by the railroads were of great assistance in making the survey.

The map of Jefferson County (fig. 3, in pocket at end of bulletin) was drawn to a scale of 3,000 feet to the inch, the outline being compiled from a War Department map of the Neches River, a Coast and Geodetic Survey map of the Gulf shore, and the county surveyor's maps of the west county boundary, and a right-of-way map of the Southern Pacific Railroad. Upon this skeleton map were plotted all the data obtained from the survey and from maps furnished by the county surveyor, the railroads, and several irrigation and land companies. The map shows also the complete system of drainage improvements proposed for the county. It should be noted, however, that drainage district No. 3 was organized and had begun construction before the project was undertaken, and the plans shown for that district are not the work of Drainage Investigations.

THE DRAINAGE PROBLEM.

As in most other counties of Texas bordering on the Gulf, the great areas of undrained and unimproved lands in Jefferson County present several problems in their reclamation. The low-lying tracts of salt marsh adjacent to the Gulf which are subject to over-

flow due to storm tides, the river marshes which are periodically submerged when the Neches overflows, the higher lands in the north half of the county which are frequently inundated by excessive rainstorms, and the necessity of coordinating drainage improvements with existing systems of irrigation canals, make the designing of a proper drainage plan for this county unusually difficult.

The first consideration in planning the drainage of a large area is to divide it into such districts that each can be drained just as soon as the landowners are ready to undertake the improvements, without regard to progress in adjoining units. Natural watershed lines ordinarily determine the boundaries of districts to be drained by gravity, while pumping units are usually planned to secure the greatest economy in cost of administration, construction, and operation. The principal faults with the gravity districts heretofore planned have been that they were established without due regard to the natural features that should determine the drainage units, and that ditches were designed without properly considering the areas that they would need to drain.

In Jefferson County the division into practicable drainage districts is complicated by the fact that Taylors Bayou is the natural outlet for 597 square miles, practically two-thirds of the county. Tide water extends up this stream and some of its branches for 25 miles from Sabine Lake. Because the ground is so level, it is impossible to secure a greater slope for the water surface below the North Fork than 0.15 foot per mile at mean tide elevation. To provide capacity for the water that will come to it, this bayou must be considerably enlarged, and to spread the cost of this work equitably over all the land drained by the watercourse is no mean undertaking.

The most practicable drainage plan could not be determined without having considered both irrigation and water transportation. This is particularly true of the latter, and in designing the drainage system herein recommended due consideration has been given to the proposed Intercoastal Canal and to the improvement of several of the larger streams for transportation purposes. The plan recommended is believed to be such that the lands may be improved in logical sequence and without unduly burdening the property owners who must pay for the reclamation, and at the same time such as will result in the most effective and economical improvements. The following pages show in detail how the various factors which enter into the plan for drainage and accessory results are provided for. Hydraulic problems and methods of construction affecting the design of the drainage works are discussed, and estimates of cost are presented for each drainage unit.

RUN-OFF.

Practically all of the water which falls upon any drainage area, except that which is returned to the air by evaporation, that which is taken up by vegetation, and that which sinks far into the earth, passes over or through the ground to the main outlet watercourse, and is termed the run-off from the area. To insure thorough drainage at all times, the ditches and the pumping machinery must be of sufficient capacity to remove the water of the heaviest rainstorm within a reasonable time. Economy, however, dictates that the design should not contemplate handling the run-off from the extremely heavy storms that occur only at intervals of several years. The exact length of time that water may stand on the ground without doing any appreciable damage to crops or without interfering materially with field operations is variable and indeterminate, but it is assumed that the surplus water should be removed from the ground surface within 24 hours.

RUN-OFF MEASUREMENTS.

Of course the best basis for determining the proper capacity of drainage channels or pumping plants is a number of measurements of the maximum flood flow following storms of the greatest severity against which it seems practicable to provide. More often than not, drainage improvements must be designed with only the most meager data of this kind, or none at all. Few opportunities for actually gaging flood run-off in this locality were presented during the survey, but the following data were obtained, which serve at least as an important check on the run-off computations discussed later.

Gagings of Taylors Bayou were made April 18, 1912, at two places near Hamshire, and the following day a gaging was made of Hillebrant Bayou at the Iron Bridge. Flood conditions prevailed then due to a storm of 3 to 4 inches on April 16, covering the watershed area, preceded by general rains that had saturated the soil. A gaging of Pine Island Bayou at the highway bridge near Voth was made May 12. Heavy rains two days previous caused the high water, but the crest of the flood occurred about 24 hours before the gaging was made; therefore the maximum run-off rate was slightly greater than that observed.

A private firm of civil engineers made gagings of Brays Bayou near Houston on December 16, 1911, during one of the wettest periods on record. The results may be used with those obtained in Jefferson County, as run-off conditions are similar. Run-off data gathered from pumping districts in southern Louisiana during several years of investigation are also available.

FACTORS AFFECTING RUN-OFF.

The amount of run-off depends upon the rate and amount of rainfall, modified by the size and form of the drainage area, the slopes of the ground, the arrangement of the watercourses, the nature of the soil, the transpiration of plants and evaporation, the natural storage reservoirs, and the drainage improvements within the watershed area. In the following discussion the rate of run-off is expressed in inches depth over the entire drainage area removed in 24 hours, or in cubic feet per second, commonly abbreviated to "second-feet." On the proper determination of the maximum rate of run-off that the drainage works should remove will depend largely the economy and efficiency of those improvements. Since the run-off is dependent upon several factors of variable values, the determination of the proper rate requires wide experience and mature judgment.

RAINFALL.

It is usual to determine first the intensity of the most severe storm against which protection should be provided. The rainfall records secured by the United States Weather Bureau in Jefferson County and the vicinity show a very uneven distribution of the precipitation, with storms of great intensity. More rainfalls and more heavy storms occur from March to September than during the rest of the year, usually; therefore overflow is the more likely to occur during the growing season. The average annual precipitation at Beaumont during the past 15 years is about 42.6 inches, at Galveston 46.3 inches, and at Lake Charles 53.9 inches.

Some of the most notable storms recorded at Beaumont during those years are as follows: October 14, 1902, 9.26 inches; November 4, 1902, 6.25 inches; and November 31, 1902, 6.87 inches. Lesser storms during and immediately following these several precipitations must have kept the ground saturated. June 25, 1905, 6.51 inches fell, preceded and followed by heavy rains, and October 14, 1906, 5.12 inches of rain occurred. During May, 1907, 19.40 inches of rain were recorded, 13.3 inches of which fell in two storms on the 23d and 30th. April 14, 1908, 5.80 inches rainfall occurred, preceded and followed by lesser storms, and during the first 10 days of July of the same year 9 inches fell. It will be noted that these excessive storms are of infrequent occurrence, but the records from all the stations show that from 1892 to 1912, between March and October each year there occurred one or more storms of 3 to 4 inches at times when the ground must have been well saturated, and that heavier storms were rather local and not general over the county.

In view of the facts stated above, it seems wise to design the drainage improvements for this county to care for the run-off from a rainfall of 4 inches in 24 hours. At very infrequent intervals the ditches

may overflow and the pumps be flooded, for short periods, but it seems economically impracticable to provide against such unusual conditions.

RUN-OFF FORMULA.

Many attempts have been made to devise a mathematical expression involving various of the factors that modify the maximum run-off rate, for use in estimating run-off when there are not actual gagings that will serve as a fairly reliable guide. A formula has been suggested by S. W. Frescoln for computing the run-off depth to be expected from any simple drainage area. It is as follows:

$$D = CM\sqrt{PF} \frac{(B+L)^{\frac{3}{2}} - (B^{\frac{3}{2}} + L^{\frac{3}{2}})}{BL}$$

in which

D = maximum rate of run-off, in inches per 24 hours, to be expected from the rainfall P .

C = a coefficient depending solely upon the physical character of the soil, and determined by experiment.

M = the ratio of total run-off to total rainfall, for the precipitation P , varying with evaporation, deep percolation, lateral seepage from the drainage channels, and duration of flood.

P = the depth of rainfall in inches in 24 hours (4 inches for Jefferson County).

F = the average slope of the ground surface of the drainage area, in feet per mile.

L = the mean length of the drainage area in miles.

B = one-half the mean width of the drainage area in miles.

For drainage areas that contain storage reservoirs, a special calculation must be made to eliminate the effect of the reservoirs. Where the main watercourse is formed by the junction of two or more large tributaries, the formula is to be applied to each tributary separately, and the proper value of the run-off depth for the entire area will be the weighted mean of the values for the parts.

APPLICATION OF THE FORMULA.

The values of L , B , and F are determined from the drainage survey, P from rainfall data as already explained, M and C by comparison with other drainage basins where gagings and other flood data have been secured.

The value of $\sqrt{F}$ is determined for each simple drainage basin by first dividing the area into units wherever there is a marked change in the surface relief, as where a flat area joins a rolling or hilly section, each unit wholly on one side of the main stream. The mean $\sqrt{F}$ is found for the course which the water will take from each corner of the unit to the outlet of the whole basin and the average of these

values is considered the $\sqrt{F}$ for that unit. The value of $\sqrt{F}$ for the whole drainage basin is the mean of the values for the separate units, each weighted according to the area of the unit. Special care is required in dividing the drainage units for a basin consisting of lands rising quickly from a main channel of small slope, that the large slope of the lands near the outlet may not have undue weight in the final value of $\sqrt{F}$. For land as level as some of the pumping districts the slopes of the water surfaces in the ditches must be used for computing $\sqrt{F}$.

The value of M for any drainage area is affected by several factors, as noted on page 12. This ratio has been determined by stream measurements for certain areas outside Jefferson County, and the values for the various districts in this county were calculated by comparison with known data, estimating the combined effect of evaporation, seepage, and percolation as 0.1 inch per day and making due allowance for other varying conditions.

The value of C , since it can not be measured directly, is to be computed by solving the formula for conditions where all the other factors, including D and M , are known. A sufficient number of repetitions of this computation covering several drainage areas having similar soil characteristics should determine reliable values for C if the various modifying factors are correctly involved in the formula. Quite a number of such computations have been made, which have given results quite uniform for each type of soil considered.

The value for C , determined in the manner just indicated, for clay soil, such as most of that in Jefferson County, is approximately 1.50. Using 0.87 for M , found in the manner described, for Taylors Bayou at the points where the run-off measurements were made, C is computed as 1.49. For the gaging of Hillebrant Bayou 0.66 was found for M and 1.56 for C . This difference in these two values for M is due principally to the great difference in the size of the areas drained. The value of C computed from the gaging of Brays Bayou near Houston agreed well with the values given above, so 1.50 was used for C in the computations for the Jefferson County ditches. The maximum rate of run-off in 24 hours of course would not exceed the rainfall.

PROPOSED PLAN OF DRAINAGE.

The general plan proposed for the drainage of that part of Jefferson County which can be wholly or partially drained by gravity consists in (1) dividing that part into its natural drainage units; (2) straightening and enlarging all the present watercourses that will become the main outlets or arteries for a complete drainage system; and (3) constructing systems of parallel ditches, spaced one-half mile apart and

running generally with the greatest slope of the land, reaching to the boundaries of each district.

The plan proposed for the remainder of the county consists in (1) dividing it into convenient pumping districts; (2) straightening and deepening certain watercourses and constructing the proposed Inter-coastal Canal, all of which will serve as outlets for the pump discharges; (3) building levees to prevent the overflow of those districts by tides, backwater from the river, or run-off from higher lands; (4) constructing systems of parallel ditches spaced 1 mile apart and reaching to all parts of each district; and (5) erecting pumping plants to lift the water from such inclosures over the protection levees. Spacing the lateral ditches 1 mile apart in each of the pumping districts will give ample relief for the present needs of the county, but it must be borne in mind that when those areas are put under cultivation additional ditches must be constructed. The number of lateral ditches should then be doubled, making them one-half mile apart. They should be fed by small collecting ditches or field laterals perpendicular to the larger ditches. It may be found practicable to use tile drains instead of open field ditches. In many newly reclaimed tracts in Louisiana these field laterals are made 4 feet deep, 4 feet wide at the top, $1\frac{1}{2}$ feet wide at the bottom, and are spaced 165 or 330 feet apart to divide the land into 10-acre or 20-acre plats between the larger ditches. Pine Island Bayou and Taylors Bayou should be improved as outlined on later pages. The work on each stream will benefit several units, and the cost should be apportioned according to the benefits to be received. The entire south end of Hardin County and a large area in Liberty County will receive direct benefit from the improvement of Pine Island Bayou, but since the present State drainage law makes no provision for cooperation between counties in doing such work it is proposed that no more work be done on that watercourse than will be necessary to meet the needs of Jefferson County. All the drainage units drained into Taylors Bayou will be benefited by the improvement of that stream below the mouth of Mayhaw Bayou near the limit of tidewater.

DRAINAGE UNITS.

GRAVITY DISTRICTS.

The gravity drainage districts are Nos. 1, 2, 4, 5, 10, 11, 12, 15, 20, 25, and 28. The district boundaries follow approximately the natural divides between adjoining drainage basins. Since the whole north end of the county, except a narrow strip along Pine Island Bayou and the Neches River marshes, is drained into Taylors Bayou, and a vast area in the south half of the county is drained ultimately into the same bayou, all of this might be combined into one great

drainage district. However, a district of this size is not organized without considerable difficulty and delay; therefore the large basin has been divided into smaller units, each independent of the others except for the cooperation necessary to improve the main watercourse. It may possibly be expedient to form one large organization embracing the smaller districts just to enlarge Taylors Bayou.

All of the land drained into Hillebrant Bayou is formed into one district, No. 10. None of the areas drained by Bayou Din, Willow Marsh, and Piviot Bayou may properly be treated as a separate unit, because each is dependent upon the lower end of Hillebrant Bayou for outlet and should share in the cost of cleaning and enlarging that bayou. All the land within the county limits that is drained by Taylors Bayou and the North Fork above their junction should have been included in district No. 11; but since a part of district No. 3, which already had been organized and had constructed ditches, is drained into the upper end of Taylors Bayou, and since a large area in Liberty County is drained into the North Fork by way of Pignut Gully, it is impracticable to form a perfect drainage unit in this instance. However, all of the land in that part of the county which is not included in district No. 3 is formed into a drainage district, and the main ditches are planned in the best possible way under the circumstances. Only part of district No. 20 can be drained into Taylors Bayou; the remainder must have an outlet eastward into Salt Bayou. Districts Nos. 25 and 28 have no outlets into existing watercourses; their drainage should be carried southward to the Intercoastal Canal.

PUMPING DISTRICTS.

That part of the county which can not be drained by gravity has been divided into convenient pumping units, and will be considered as districts Nos. 6, 7, 8, 9, 13, 14, 16, 17, 18, 19, 21, 22, 23, 24, 26, 27, 29, 30, 31, and 32. The marshes bordering on the Neches River were divided into such units that each would be entirely independent of all others, the bluff and the river front forming the complete boundaries of each.

District No. 8 is a small area between Beaumont and the Neches River, southeast of the city. About half of the district is high land and the remainder is river marsh. Because the Neches River is being shortened by several cut-offs at this point, it is deemed best not to present plans for drainage at this time. The newly graded Mansfield Ferry road across the marsh forms an excellent levee between this district and No. 9. Districts Nos. 13, 14, and 16 can be only partially drained by gravity; the south end of district No. 13 is very low and subject to frequent overflow. In order to insure

perfect drainage of this entire district, a levee must be built along Taylors and Hillebrant Bayous, and pumps installed at the mouth of Rodair Bayou. District No. 14 surrounds but does not include about 3,200 acres which a company proposes to drain independently. This tract might be included in district No. 14 without materially affecting the plans presented in this report. The south end of this district is very low and at times water will have to be pumped into Taylors Bayou, at the mouth of Alligator Bayou. It will not be necessary to construct levees to protect this area because the embankments of the Kansas City Southern Railroad and the Dallas and Sabine branch of the Texas & New Orleans Railroad will afford ample protection against backwater. The drainage from the whole of district No. 16 should be pumped into the ship canal at the mouth of Blacks Bayou. A levee must be constructed along the Neches River and the ship canal to protect the low land.

If found more convenient for the purpose of organization, district No. 9 may be divided into two districts of equal size, the canal connecting the Neches River with the McFaddin irrigation pumping plant at the narrowest part of the marsh being the dividing line. However, such a division would require the construction of an additional drainage pumping plant, with consequent increase in the cost per acre for the reclamation. It will be possible also to divide district No. 16 into two districts, the river marsh being one and the remainder of the land being the other. The bluff which forms the south boundary of the marsh becomes less marked as Sabine Lake is approached until it disappears entirely at a point about 1 mile from the lake. This would necessitate the construction of a levee from the end of the bluff to the lake and two pumping plants instead of one, thus increasing the cost of reclamation in each district.

South of Taylors Bayou the division of the land into pumping units is more or less arbitrary. At the present time there are no data at hand for determining whether one size of district on such land is more economical than another. In Louisiana there are districts of much greater size than the largest here recommended and others much smaller than the smallest here planned. Districts Nos. 18 and 19 may be combined into one district if more convenient, which would require changing the location of pumping plant of No. 18 and revising the ditch grades. Districts Nos. 21 and 24 can be combined or separated into smaller districts by rearranging the ditches and relocating the pumping plants. Districts Nos. 26 and 27, also, may be combined into one large district or separated into several smaller ones. Districts Nos. 29 and 30 may be divided into a number of smaller districts, but it would be impracticable to combine them into a large one on account of their shapes and relative location.

Although the Intercoastal Canal must be constructed before the reclamation of districts Nos. 24, 25, 26, 27, 28, 29, 30, and 32 can be carried out according to the plans presented herein, the cost of its construction is not charged to these districts. They are dependent upon the Intercoastal Canal for outlet, but since that waterway will be a benefit to the whole county as well as to adjoining counties and as it is possible that Federal appropriations will be made to help carry out this work no estimate is made of its cost. Should a different route be selected for the canal, the plans for the drainage of the above-named districts must be changed accordingly.

CITIES AND TOWNS.

The city of Beaumont is not included in any drainage district under the present arrangement. Some parts of the city will receive direct benefit when certain ditches of district No. 10 are constructed, but just what this benefit will be depends in part upon the location and construction of sewers. The greater part of Beaumont is drained into the Neches River and may be considered as a separate and independent drainage district. Port Arthur also is excluded from any of the enumerated drainage districts. It lies on very low ground and is affected by the same conditions as districts Nos. 16 and 17, but it has already built its own drainage system, including open ditches and pumping plant. The towns of Sabine and Sabine Pass and the half-mile strip of land connecting them, which have been filled in by suction dredges working in the Sabine Pass channel, are also excluded from any of the numbered districts.

DRAINAGE DITCHES.

CAPACITIES AND DIMENSIONS.

The first step in designing the drains for each district to be drained wholly or partly by gravity was to determine the area that will be drained by each ditch, including the areas drained by each main ditch at the points where laterals or submains will enter. For each pumping district only the whole area and the area drained by each main ditch was determined. The rate of run-off from each such area was computed by Frescoln's formula, as previously described, to find the required capacity of each ditch.

A profile along the route of each ditch was platted from the data on the map, and the grades of the ditch bottoms were determined from those profiles. The Chezy formula, $V = C\sqrt{RS}$, was used in computing the sizes of the ditches, C being determined by Kutter's formula with 0.030 as the value of the roughness coefficient n . All laterals in pumping districts were made of such size that they could be con-

structed by floating dipper dredges; the majority of them, therefore, will be much larger than necessary to carry the water that will reach them, and thus will provide large reservoir capacity. The minimum depth was fixed for all ditches at 6 feet, in order to provide (1) sufficient depth to float a dredge, (2) adequate outlet for tile drains and field ditches, and (3) better drainage along the ditches before the field drains have been constructed by the individual owners. The minimum bottom width of ditch for gravity districts was fixed at 2 feet, which is as narrow as it is practicable to make. With bottom width 2 feet, depth 6 feet, and side slopes 1 to 1, the top width of the minimum ditch will be 14 feet. The bottom widths for minimum ditches in the pumping districts are planned as follows: For the minimum depth of 6 feet, bottom width 12 feet; depths $6\frac{1}{2}$ to 7 feet, bottom width 10 feet; depths $7\frac{1}{2}$ to 8 feet, bottom width 8 feet; depths $8\frac{1}{2}$ to 9 feet, bottom width 6 feet; depths $9\frac{1}{2}$ to 10 feet, bottom width 4 feet. With side slopes 1 to 1, the top widths of such ditches will all be 23 to 24 feet. In the Appendix will be found a tabular statement of the sizes of the various ditches.

BERMS.

When constructing the ditches the waste material must be deposited far enough from the edge of the excavation so that the weight of the spoil banks will not cause caving of the sides of the ditch. For all minimum ditches there should be a clear berm of 6 feet between the toe of the spoil bank and the edge of the ditch; for ditches having bottom widths greater than the minimum but less than 8 feet, the berm should be 8 feet wide; and for ditches that have bottom widths of 8 feet or more, the berm should be 10 feet.

CLEARING RIGHT OF WAY.

A right of way must be cleared for the ditches located in timbered areas, and the width of such clearing depends on the width of the ditch. The total acreage to be cleared for each district is shown in the cost estimates, the area required for each ditch having been computed on the following basis:

Widths of right of way to be cleared.

Top width of ditch.	Width of clearing.	Top width of ditch.	Width of clearing.
<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Minimum to 20	60	41 to 46	140
21 to 26	80	47 to 53	160
27 to 33	100	54 to 60	180
34 to 40	120	61 to maximum.	200

LEVEES.

HEIGHT AND CROSS SECTION.

The height of the levees should be at least 1 to 2 feet above the highest water expected. The gagings at Beaumont by the War Department show a big rise in the Neches River after every heavy rain over its drainage basin. Following the heavy rains of December, 1911, the gage registered 5.12 feet above Gulf level, but as the first available record of this gage is for January 4, 1912, it probably does not show the extreme height of the December flood. In March, 1912, the gage registered 4.5 feet, and in May, 1912, 5.3 feet. Assuming that the high-water profile of the Neches is a straight line, beginning with the elevation 0.0 of mean low tide at the mouth of the river and passing through elevation 7.0 at Beaumont, the high-water mark at the mouth of Pine Island Bayou would be 9 feet; actual high-water marks at the Neches Canal Co. pumping plant on Pine Island Bayou have an elevation of 15.3 feet. This assumed high-water profile gives elevation of 8.5 feet at Colliers Ferry, 7.5 feet 1 mile above the Southern Pacific Railroad bridge at Beaumont, 6 feet at Mansfield Ferry, 3 feet at the Port Arthur Rice & Irrigation Co. pumping plant, and 2 feet at Port Neches. Since the general elevation of the marsh of district No. 6 is about 3 feet, the levee to protect it must be at least 13 feet high at the Neches Canal pumping plant and $6\frac{1}{2}$ feet high at Colliers Ferry. The levee for district No. 7, whose elevation averages about 2 feet, must be at least $7\frac{1}{2}$ feet high at Colliers Ferry and $6\frac{1}{2}$ feet high 1 mile above the Southern Pacific Railroad bridge at Beaumont. The levee for district No. 9 must be at least 5 feet high at Mansfield Ferry and 1 foot high at the Port Arthur Rice & Irrigation Co. pumping plant, assuming that high tides have no effect above that point. Before construction is begun on the levees for districts Nos. 6, 7, and 9 further investigations should be made to determine the elevation of high water between Neches Canal Co. pumping plant and Port Neches.

The daily range of tide in the Gulf along Jefferson County is ordinarily 0.5 to 1.5 feet, but heavy winds blowing directly against the shore for considerable periods cause rises of several feet. Sometimes the storm tide affects only a small part of the coast line, sometimes it extends the whole width of the county. The highest tide in this locality was in 1900, when the water rose 16 feet at Galveston. The United States Coast and Geodetic Survey gages at Galveston show that from 1888 to 1890 there were 6 storm tides 2.7 feet or more above mean low tide, and from 1904 to 1909 there were 7 tides 2.5 feet or more above mean low tide. The highest of these were 4.9 feet in 1890 and 4.8 feet in 1909. In the streams and bayous several miles back from the coast the tides are neither so great nor so prolonged. To pro-

tect the districts in the southern part of the county against storms equal to those recorded at Galveston from 1888 to 1890 and from 1904 to 1909, all levees should be at least 4 feet high, which is in accord with the general practice in Louisiana, and those fronting directly on the Gulf should be at least 6 feet high. It is assumed that because such extraordinary storms as that of 1900 occur only at very long intervals, protection against loss by them will be by insurance rather than by levees of sufficient height to prevent overflow.

The proper cross sections of levees will depend upon the material used and the nature of the foundation. Where the material is dense and the foundation firm, as along the Neches River, the top width should be not less than 4 feet and the side slopes not steeper than 2 horizontal to 1 vertical. On the soft marshland in the southern part of the county the top width of levees should be not less than 6 feet and the side slopes not steeper than 3 horizontal to 1 vertical. The material excavated from the ditches designed for the latter territory will be much more than enough to build levees with the specified dimensions; therefore it will be possible to use many of the levees as roadways when they are properly settled and smoothed.

CONSTRUCTION.

In districts Nos. 6 and 7, which are covered with timber, all stumps, logs, and other vegetable matter should be removed from the base of the levees, which should then be plowed before any material is deposited. These precautions will insure a good bond between the old and the new material and prevent excessive seepage. In district No. 9 and others in the southern part of the county that are located on the open prairie where the ground is firm and above ordinary water level, a shallow ditch along the center line will insure a good bond. The berms for these levees should be at least 10 feet wide.

On the soft marsh lands levees must be constructed with great care, to prevent seepage and caving. They should be built in horizontal layers, each layer given some time to dry before the next is added; this will prevent yielding of the base as the material is deposited. The orange-peel bucket dredge is perhaps best adapted to this work because it can bring suitable material from below the soft surface mud, and by dropping the dirt from a considerable height can compact it in the levee. In order to prevent excessive pressure on the ditch banks which might cause sloughing of the soft earth, the berms in these marshes should be 15 to 20 feet wide. After the levee has dried sufficiently it should be smoothed and brought to grade. Usually prairie grass will soon cover the new levee and help keep it in shape. Careful grazing on the levees will give some protection against burrowing animals.

PUMPING PLANTS.

The design of pumping plants for drainage districts involves the study of many technical phases of their construction and operation, but experience seems to indicate that for the pumping districts herein recommended the centrifugal pump driven by steam power is the best type. Therefore the cost estimates of the plants are based upon this kind of equipment. Possibly electrical power or internal combustion engines may be found economical for some of the pumping plants.

After computing the maximum rate of run-off from each entire district by Frescoln's formula, a proper deduction was made for estimated storage in the ditches in order to determine the maximum rate at which the pumps would be required to handle the water. The pump sizes were computed by assuming the velocity through the pumps to be 12 feet per second. The engine sizes were determined by assuming that the water must be lifted 4 feet in all districts in the southern part of the county, 6 feet in district No. 9, 7 feet in district No. 7, and 8 feet in district No. 6. In times of excessive high water it might be necessary to lift the water to greater heights, but this contingency would be met by overloading or speeding up the engines.

BRIDGES, CULVERTS, AND FLUMES.

A complete plan of drainage must include provision for crossing highways, railroads, and irrigation canals, and the cost estimate must include the expense for the necessary bridges, culverts, and flumes. The sizes of openings and the types of structures recommended are indicated herewith.

HIGHWAY CROSSINGS.

Where drainage ditches with 2-foot bottom width are crossed by highways, culverts are recommended. Where such a ditch will have to carry only about one-fourth its computed capacity, a 36-inch corrugated iron pipe 35 feet long with a straight concrete head wall at each end will be suitable. Where the required capacity is about one-third the computed capacity, a similar culvert of 48-inch pipe is recommended. Where required capacities are approximately one-half, three-fourths, and the whole computed capacities, reinforced concrete box culverts with openings 4 by 4 feet, 5 by 5 feet, and 5 by 6 feet, respectively, should be provided. These box culverts should each be 20 feet long, with straight head walls. For ditches with 4-foot bottom width, similar culverts 5 by 8 feet with flaring wing walls are estimated.

Steel I-beam bridges with 20-foot width of roadway are recommended for crossing ditches with 6, 8, 10, and 12 foot bottom widths; the spans should be 13, 14, 16, and 20 feet, respectively. For crossing larger ditches, steel pony truss bridges of the Warren type, with 16-foot roadways, seem most suitable. The spans should exceed the

bottom widths of the ditches by 8 feet for 14 to 25 foot widths, by 9 feet for 30-foot widths, and by 10 feet for 35 to 50 foot widths. All bridges should be placed on concrete abutments.

RAILWAY CROSSINGS.

Culverts of 36-inch and 48-inch pipe are recommended where railways cross drainage ditches that will need to carry not more than about one-fourth or one-third, respectively, of the computed capacities of ditches with 2-foot bottom widths, as planned for highway crossings. All other railway crossings are estimated as half-through plate girder bridges on concrete abutments, with spans about equal to one-half the sum of the top and bottom widths of the drainage ditch.

IRRIGATION CANAL CROSSINGS.

As all irrigation canals consist of two levees between which the water flows over the natural ground surface, these must be carried over the drainage ditches at the crossings. It is impossible to determine the exact number of such crossings there will be, as many of the present irrigation canals may not be in use when the drainage ditches are constructed, and the data are not at hand to show where the proposed ditches cross all the irrigation laterals. The cost has been estimated for each crossing of a drainage ditch with a main irrigation canal in use at the time of the survey, and the total for each district has been included in the total cost estimates given on later pages. Culverts of 36-inch and 48-inch pipe should be used for the small ditches under the same conditions as explained for highway crossings. Where it is expected that the drainage ditch will carry one-half the computed capacity of the smallest ditch recommended, or more, the irrigation canal is to cross the drainage ditch in a wood flume supported on timber bents or piles. Each flume should be about 10 feet longer than the top width of the drainage ditch, thus allowing about 5 feet at each end for a firm bond with the bottom of the irrigation canal to prevent leakage.

PINE ISLAND BAYOU IMPROVEMENT.

All trees and brush should be cleared from the old channel of Pine Island Bayou for a strip 100 feet wide, which will give the present channel a capacity of 1,600 cubic feet per second, equivalent to about 0.6 inch run-off per 24 hours from the drainage area above the Jefferson-Liberty County line. From the county line to Voth, such a strip would contain 270 acres; clearing this would cost, at \$40 per acre, \$10,800. Divided along districts Nos. 1, 2, and 4 in proportion to their areas, this cost would amount to \$1,605, \$3,870, and \$5,325, respectively, or 27.7 cents per acre.

TAYLORS BAYOU IMPROVEMENT.

The drainage areas and computed maximum run-off for Taylors Bayou at several points have been determined as follows:

Maximum run-off for Taylors Bayou.

Point of run-off.	Drainage area.	Total run-off.		
		<i>Sq. miles.</i>	<i>Inches.</i>	<i>Second-feet.</i>
At West Port Arthur railroad bridge.....		597	0.27	4,400
Just below Hillebrant Bayou.....		459	.35	4,400
Just above Hillebrant Bayou.....		312	.48	4,100
Just below North Fork of Taylors Bayou.....		280	.55	4,100
Just above North Fork of Taylors Bayou.....		120	.55	1,800
Just below Mayhaw Bayou.....		105	.63	1,800
Just above Mayhaw Bayou.....		30	1.10	1,000
At Hamshire railroad bridge.....		22	1.60	945

The total fall available in the 25 miles from the mouth of Mayhaw Bayou to West Port Arthur is only 4 feet. As indicated on the map, below Hillebrant Bayou there should be 5 cut-offs having a total length of 1.7 miles, and between this bayou and the North Fork of Taylors Bayou there should be 9 cut-offs aggregating 1.5 miles, with bottom width of 85 feet, depth 20 feet, and side slopes 1 to 1. The whole present channel of Taylors Bayou below the North Fork, except the cut-off bends, should be enlarged to the same dimensions. The fall below Hillebrant Bayou should be 0.16 foot per mile, and between that stream and the North Fork about 0.14 foot per mile. With these slopes the elevations of water surface above mean tide level will be 0.0 at West Port Arthur, 1.3 at Hillebrant Bayou, and 2.6 at the North Fork. Between the North Fork and Mayhaw Bayou the channel should be 50 feet in bottom width, 17 feet deep, with 1 to 1 side slopes and a fall of 0.14 foot per mile. The water surface at Mayhaw Bayou then would have the elevation 3.4. Between this point and the railroad bridge at Hamshire the available fall is 0.88 foot per mile, which will give ample capacity to a ditch of 25-foot bottom and 12-foot depth. The channel here recommended will prevent overflow at seasons of ordinary range of tide, which is small. However, on rare occasions severe storms will be accompanied by high winds that will raise the tides sufficient to obliterate the slight fall obtainable on the lower part of the bayou, and at such times short periods of overflow may be expected.

The excavation required by the improvement recommended is roughly estimated thus:

Excavation in Taylors Bayou.

Section.	Distance.		Excavation.
	<i>Miles.</i>		<i>Cubic yds.</i>
West Port Arthur to Hillebrant Bayou.....	8.0		2,025,000
Hillebrant Bayou to North Fork.....	9.7		2,119,000
North Fork to Mayhaw Bayou.....	6.0		469,000
Mayhaw Bayou to Hamshire.....	5.0		325,000
Total.....			4,938,000

The total cost of the four sections would be, at 6 cents per cubic yard below Mayhaw Bayou and 8 cents per yard for the upper section, \$302,780. If the cost of each section is to be divided among the districts drained through that section in proportion to their areas, the total cost to each will be, according to the estimate: District No. 3, \$61,175; No. 10, \$36,450; No. 11, \$151,174; No. 12, \$15,639; No. 13, \$4,860; No. 17, \$1,215; No. 18, \$9,112; No. 19, \$5,637; and No. 20, \$17,518.

The improvement of Taylors Bayou will necessitate building a bridge across the new channel at La Belle. This bridge is estimated to cost \$7,100, which sum should be distributed among districts Nos. 3, 11, 12, and 20, in proportion to their areas. The amount to be charged to each would then be as follows: District No. 3, \$910; No. 11, \$4,770; No. 12, \$710; and No. 20, \$710. The cost of this bridge has been included with that of excavation for the Taylors Bayou improvement in the "Estimate of cost" rather than with the estimates for other bridges.

ESTIMATE OF COST.

The summarized estimate of total cost for each drainage district proposed for Jefferson County is given herewith, including the cost of operating each pumping plant. The acreages benefited do not include the areas covered by ditches and spoil banks.

Clearing right of way for all ditches located in the woods has been estimated at \$50 per acre; this includes the cost of blasting all stumps 12 inches or more in diameter in the path of the dredge ditches and of grubbing all stumps, large and small, from the paths of the lateral ditches. The purchase cost of right of way 100 feet wide for the outlets for districts Nos. 20, 25, and 28, at \$5 per acre, is included in the estimates. Excavation of ditches 8 feet or more in bottom width is estimated at 8 cents per cubic yard and smaller ditches at 10 cents, but the enlargement of Taylors Bayou below Mayhaw Bayou and on Hillebrant Bayou below Bayou Din is estimated at 6 cents per cubic yard. These prices are based upon average contract prices where payment is made in cash and not in bonds of the district which the contractor must accept at par and sell at a discount. The amounts of excavation were estimated by determining the average depth of cut, to the nearest half foot, from the profiles of the ditches. Where the material is to be placed in a levee, the price is increased 2 cents per yard to provide for putting all dirt on one side of the ditch and smoothing the embankment.

The cost of drainage pumping plants varies widely with the type of machinery, the character of foundation, and the expense of transportation to the site. The costs estimated for the plants in Jefferson County are average values from a large number of estimates made

by an eminent firm of contracting mechanical engineers for engines, pumps, and foundations, plus estimates for the buildings. It is possible that actual costs may vary considerably from those given. The annual costs of operation given include fuel, repairs, engineer's salary, and depreciation. A table prepared by the above-mentioned engineers showing comparative fuel costs of several different types of pumping plants was used in estimating the cost of fuel oil for each district.

The cost of legal, engineering, and incidental expenses was estimated at 10 per cent of the cost of construction.

COST BY DISTRICTS.

Drainage district No. 1:

Clearing right of way, 158 acres in woods, at \$50 per acre.....	\$7, 900
Excavation—	
65,500 cubic yards, at 8 cents per yard.....	5, 240
129,900 cubic yards, at 10 cents per yard.....	12, 990
Improving Pine Island Bayou.....	1, 605
Bridges, etc., 1 railroad bridge, 60 feet.....	2, 850
Engineering and legal expenses, 10 per cent.....	3, 058
Total.....	33, 643

Acres benefited in district, 5,790.

Average cost per acre, \$5.80.

Drainage district No. 2:

Clearing right of way, 146 acres in woods, at \$50 per acre.....	7, 300
Excavation—	
173,600 cubic yards, at 8 cents per yard.....	13, 888
352,650 cubic yards, at 10 cents per yard.....	35, 265
Improving Pine Island Bayou.....	3, 870
Bridges, etc., 2 bridges, 8 culverts.....	5, 650
Engineering and legal expenses, 10 per cent.....	6, 597
Total.....	72, 570

Acres benefited in district, 13,980.

Average cost per acre, \$5.20.

Drainage district No. 3:

(Plans by private engineers; construction work completed.)

Drainage district No. 4:

Clearing right of way, 190 acres in woods, at \$50 per acre.....	9, 500
Excavation—	
138,050 cubic yards, at 8 cents per yard.....	11, 044
623,300 cubic yards, at 10 cents per yard.....	62, 330
Improving Pine Island Bayou.....	5, 325
Bridges, etc., 1 bridge, 14 culverts, 3 flumes.....	10, 575
Engineering and legal expenses, 10 per cent.....	9, 875
Total.....	108, 652

Acres benefited in district, 19,200.

Average cost per acre, \$5.65.

Drainage district No. 5:

Clearing right of way, 108 acres in woods, at \$50 per acre.....	\$5,400
Excavation, 165,200 cubic yards, at 10 cents per yard.....	16,520
Bridges, etc., 19 culverts.....	6,475
Engineering and legal expenses, 10 per cent.....	2,840
Total.....	31,235

Acres benefited in district, 6,560.

Average cost per acre, \$4.75.

Drainage district No. 6:

Clearing right of way, 226 acres in woods, at \$50 per acre.....	11,300
Excavation—	
98,700 cubic yards, at 8 cents per yard.....	7,896
456,100 cubic yards, at 10 cents per yard.....	45,610
Pumping plant, complete.....	34,000
Engineering and legal expenses, 10 per cent.....	9,881
Total.....	108,687

Acres benefited in district, 2,670.

Average cost per acre, \$40.70.

Annual cost of operation: Total, \$3,875; per acre, \$1.45.

Drainage district No. 7:

Clearing right of way, 110 acres in woods, at \$50 per acre.....	5,500
Excavation—	
67,500 cubic yards, at 8 cents per yard.....	5,400
193,000 cubic yards, at 10 cents per yard.....	19,300
Pumping plant, complete.....	38,500
Engineering and legal expenses, 10 per cent.....	6,870
Total.....	75,570

Acres benefited in district, 2,100.

Average cost per acre, \$36.

Annual cost of operation: Total, \$3,895; per acre, \$1.85.

Drainage district No. 8:

(No plans prepared. See p. 15.)

Drainage district No. 9:

Excavation—	
136,900 cubic yards, at 8 cents per yard.....	10,952
688,600 cubic yards, at 10 cents per yard.....	68,860
Bridges, etc., 2 flumes.....	600
Pumping plant, complete.....	37,000
Engineering and legal expenses, 10 per cent.....	11,741
Total.....	129,153

Acres benefited in district, 6,440.

Average cost per acre, \$20.05.

Annual cost of operation: Total, \$4,960; per acre, \$0.77.

Drainage district No. 10:

Clearing right of way, 748 acres in woods, at \$50 per acre.....	37,400
Excavation—	
2,812,450 cubic yards, at 8 cents per yard.....	224,996
2,694,550 cubic yards, at 10 cents per yard.....	269,455
1,201,700 cubic yards, at 6 cents per yard.....	72,102
Bridges, etc.: 31 bridges, 103 culverts, 3 flumes.....	73,265
Taylor's Bayou improvement.....	36,450
Engineering and legal expenses, 10 per cent.....	71,346
Total.....	785,014

Acres benefited in district, 90,110.

Average cost per acre, \$8.70.

Drainage district No. 11:

Clearing right of way, 697 acres in woods, at \$50 per acre.....	\$34,850
Excavation—	
5,142,500 cubic yards, at 8 cents per yard.....	411,400
3,111,750 cubic yards, at 10 cents per yard.....	311,175
Improving Taylors Bayou.....	155,944
Bridges, etc., 36 bridges, 77 culverts, 13 flumes.....	84,830
Engineering and legal expenses, 10 per cent.....	99,820
Total.....	1,098,019

Acres benefited in district, 95,820

Average cost per acre, \$11.45.

Drainage district No. 12:

Clearing right of way, 10 acres in woods, at \$50 per acre.....	500
Excavation—	
46,350 cubic yards, at 8 cents per yard.....	3,708
455,700 cubic yards, at 10 cents per yard.....	45,570
Improving Taylors Bayou.....	16,349
Bridges, etc., 2 bridges, 8 culverts.....	3,925
Engineering and legal expenses, 10 per cent.....	7,005
Total.....	77,057

Acres benefited in district, 13,940.

Average cost per acre, \$5.55.

Drainage district No. 13:

Excavation—	
535,650 cubic yards, at 8 cents per yard.....	42,852
321,100 cubic yards, at 10 cents per yard.....	32,110
180,600 cubic yards, at 12 cents per yard.....	21,672
Improving Taylors Bayou.....	4,860
Bridges, etc., 3 bridges, 14 culverts.....	6,600
Pumping plant, complete.....	39,000
Engineering and legal expenses, 10 per cent.....	14,709
Total.....	161,803

Acres benefited in district, 12,490.

Average cost per acre, \$12.95.

Annual cost of operation: Total, \$5,640; per acre, \$0.50.

Drainage district No. 14:

Excavation—	
1,140,100 cubic yards, at 8 cents per yard.....	91,208
723,100 cubic yards, at 10 cents per yard.....	72,310
Bridges, etc., 10 bridges, 35 culverts.....	22,625
Pumping plant, complete.....	46,000
Engineering and legal expenses, 10 per cent.....	23,214
Total.....	255,357

Acres benefited in district, 25,160.

Average cost per acre, \$10.15.

Annual cost of operation: Total, \$8,400; per acre, \$0.33.

Drainage district No. 15:

Excavation, 103,750 cubic yards, at 10 cents per yard.....	10,375
Bridges, etc., 5 culverts, 1 flume.....	2,400
Engineering and legal expenses, 10 per cent.....	1,278
Total.....	14,053

Acres benefited in district, 2,850.

Average cost per acre, \$4.95.

Drainage district No. 16:

Excavation—

323,100 cubic yards, at 8 cents per yard.....	\$25,848
657,700 cubic yards, at 10 cents per yard.....	65,770
Bridges, etc., 4 culverts.....	750
Pumping plant, complete.....	45,000
Engineering and legal expenses, 10 per cent.....	13,737
Total.....	151,105

Acres benefited in district, 11,220.

Average cost per acre, \$13.45.

Annual cost of operation: Total, \$6,520; per acre, \$0.58.

Drainage district No. 17:

Excavation—

225,950 cubic yards, at 8 cents per yard.....	18,076
337,150 cubic yards, at 10 cents per yard.....	33,715
Taylor's Bayou improvement.....	1,215
Pumping plant, complete.....	23,000
Engineering and legal expenses, 10 per cent.....	7,601
Total.....	83,607

Acres benefited in district, 3,620.

Average cost per acre, \$23.10.

Annual cost of operation: Total, \$3,745; per acre, \$1.03.

Drainage district No. 18:

Excavation—

1,017,500 cubic yards, at 8 cents per yard.....	81,400
428,950 cubic yards, at 10 cents per yard.....	42,895
Taylor's Bayou improvement.....	9,112
Pumping plant, complete.....	39,500
Engineering and legal expenses, 10 per cent.....	17,291
Total.....	190,198

Acres benefited in district, 22,560.

Average cost per acre, \$8.45.

Annual cost of operation: Total, \$8,045; per acre, \$0.36.

Drainage district No. 19:

Excavation—

174,340 cubic yards, at 8 cents per yard.....	13,947
227,400 cubic yards, at 10 cents per yard.....	22,740
Improving Taylor's Bayou.....	5,637
Pumping plant, complete.....	20,500
Engineering and legal expenses, 10 per cent.....	6,282
Total.....	69,106

Acres benefited in district, 4,530.

Average cost per acre, \$15.25.

Annual cost of operation: Total, \$3,950; per acre, \$0.87.

Drainage district No. 20:

Excavation—

60,900 cubic yards, at 8 cents per yard.....	4,872
1,455,750 cubic yards, at 10 cents per yard.....	145,575
99,200 cubic yards, at 12 cents per yard.....	11,904
Improving Taylor's Bayou.....	18,228
Right of way for outlet, 92 acres, at \$5 per acre.....	460
Engineering and legal expenses, 10 per cent.....	18,104
Total.....	199,143

Acres benefited in district, 15,400.

Average cost per acre, \$12.95.

Drainage district No. 21:

Excavation—

976,700 cubic yards, at 8 cents per yard.....	\$78,136
325,000 cubic yards, at 10 cents per yard.....	32,500
Pumping plant, complete.....	30,500
Engineering and legal expenses, 10 per cent.....	14,114

Total.....	155,250
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Acres benefited in district, 16,820.

Average cost per acre, \$9.25.

Annual cost of operation: Total, \$6,430; per acre, \$0.38.

Drainage district No. 22:

Excavation—

523,200 cubic yards, at 8 cents per yard.....	41,856
577,400 cubic yards, at 10 cents per yard.....	57,740
Pumping plant, complete.....	24,000
Engineering and legal expenses, 10 per cent.....	12,360

Total.....	135,956
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Acres benefited in district, 10,480.

Average cost per acre, \$12.95.

Annual cost of operation: Total, \$6,525; per acre, \$0.62.

Drainage district No. 23:

Excavation—

997,750 cubic yards, at 8 cents per yard.....	79,820
455,300 cubic yards, at 10 cents per yard.....	45,530
Bridges, etc., 2 bridges.....	1,600
Pumping plant, complete.....	28,500
Engineering and legal expenses, 10 per cent.....	15,545

Total.....	170,995
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Acres benefited in district, 14,440.

Average cost per acre, \$11.85.

Annual cost of operation: Total, \$5,830; per acre, \$0.40.

Drainage district No. 24:

Excavation—

1,536,850 cubic yards, at 8 cents per yard.....	122,948
36,400 cubic yards, at 10 cents per yard.....	3,640
Pumping plant, complete.....	35,000
Engineering and legal expenses, 10 per cent.....	16,159

Total.....	177,747
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Acres benefited in district, 19,590.

Average cost per acre, \$9.10.

Annual cost of operation: Total, \$7,250; per acre, \$0.37.

Drainage district No. 25:

Excavation—

59,400 cubic yards, at 8 cents per yard.....	4,752
1,484,250 cubic yards, at 10 cents per yard.....	148,425
33,600 cubic yards, at 12 cents per yard.....	4,032
Right of way for outlet, 36 acres, at \$5 per acre.....	180
Engineering and legal expenses, 10 per cent.....	15,739

Total.....	173,128
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Acres benefited in district, 10,970.

Average cost per acre, \$15.80.

Drainage district No. 26:

Excavation—

935,700 cubic yards, at 8 cents per yard.....	\$74, 856
227,150 cubic yards, at 10 cents per yard.....	22, 715
Pumping plant, complete.....	29, 500
Engineering and legal expenses, 10 per cent.....	12, 707

Total.....	139, 778
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Acres benefited in district, 15,830.

Average cost per acre, \$8.85.

Annual cost of operation: Total, \$6,125; per acre, \$0.39.

Drainage district No. 27:

Excavation, 1,570,350 cubic yards, at 8 cents per yard.....	125, 628
Pumping plant, complete.....	34, 000
Engineering and legal expenses, 10 per cent.....	15, 963

Total.....	175, 591
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Acres benefited in district, 19,490.

Average cost per acre, \$9.

Annual cost of operation: Total, \$7,105; per acre \$0.36

Drainage district No. 28:

Excavation—

2,275,450 cubic yards, at 10 cents per yard.....	227, 545
6,000 cubic yards, at 12 cents per yard.....	720
Right of way for outlet, 26 acres, at \$5 per acre.....	130
Engineering and legal expenses, 10 per cent.....	22, 827

Total.....	251, 222
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Acres benefited in district, 14,160

Average cost per acre, \$17.75

Drainage district No. 29:

Excavation—

1,329,300 cubic yards, at 8 cents per yard.....	106, 344
338,500 cubic yards, at 10 cents per yard.....	33, 850
Pumping plant, complete.....	35, 000
Engineering and legal expenses, 10 per cent.....	17, 519

Total.....	192, 713
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Acres benefited in district, 19,930.

Average cost per acre, \$9.65.

Annual cost of operation: Total, \$7,275; per acre, \$0.36.

Drainage district No. 30:

Excavation—

1,183,550 cubic yards, at 8 cents per yard.....	94, 684
318,500 cubic yards, at 10 cents per yard.....	31, 850
Pumping plant, complete.....	31, 500
Engineering and legal expenses, 10 per cent.....	15, 803

Total.....	173, 837
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Acres benefited in district, 17,100.

Average cost per acre, \$10.15.

Annual cost of operation: Total, \$6,535; per acre, \$0.38.

Drainage district No. 31:

Excavation—

690,750 cubic yards, at 8 cents per yard.....	\$55,260
564,200 cubic yards, at 10 cents per yard.....	56,420
Pumping plant, complete.....	26,000
Engineering and legal expenses, 10 per cent.....	13,768

Total..... 151,448

Acres benefited in district, 12,800.

Average cost per acre, \$11.85.

Annual cost of operation: Total, \$5,370; per acre, \$0.42.

Drainage district No. 32:

Excavation—

278,350 cubic yards, at 8 cents per yard.....	22,268
86,800 cubic yards, at 10 cents per yard.....	8,680
Pumping plant, complete.....	20,500
Engineering and legal expenses, 10 per cent.....	5,145

Total..... 56,593

Acres benefited in district, 4,620.

Average cost per acre, \$12.25.

Annual cost of operation: Total, \$3,420; per acre, \$0.74.

SUMMARY OF AREAS AND COSTS.

No. of district.	Areas.				Length of ditches.	Cost.	
	Open prairie and marsh.	Timbered.	Total.	Benefited.		Total.	Average.
	Acres.	Acres.	Acres.	Acres.	Miles.		Per acre.
1.....	850	5,100	5,950	5,790	16.9	\$33,643	\$5.80
2.....	10,720	3,620	14,340	13,980	43.4	72,570	5.20
3.....	46,760		46,760				
4.....	10,490	9,100	19,590	19,200	58.0	108,652	5.65
5.....	1,320	5,350	6,670	6,560	17.8	31,235	4.75
6.....	2,870	12,870	2,870	2,670	14.7	108,687	40.70
7.....	2,220	1,520	2,220	2,100	9.4	75,570	36.00
8.....	1,150		1,150				
9.....	6,720		6,720	6,440	23.3	129,153	20.05
10.....	78,260	14,200	92,460	90,110	303.2	785,014	8.70
11.....	81,470	17,000	98,470	95,820	307.8	1,098,019	11.45
12.....	13,380	820	14,200	13,940	40.2	77,057	5.55
13.....	12,900		12,900	12,490	47.7	161,803	12.95
14.....	25,770		25,770	25,160	75.5	255,357	10.15
15.....	2,900		2,900	2,850	8.7	14,053	4.95
16.....	11,650		11,650	11,220	41.4	151,105	13.45
17.....	3,830		3,830	3,620	17.3	83,607	23.10
18.....	23,060		23,060	22,560	44.6	190,198	8.45
19.....	4,600		4,600	4,530	14.6	69,106	15.25
20.....	15,890		15,890	15,400	58.5	199,143	12.95
21.....	17,410		17,410	16,820	43.2	155,250	9.25
22.....	10,880		10,880	10,480	33.2	135,956	12.95
23.....	15,000		15,000	14,440	46.3	170,995	11.85
24.....	20,230		20,230	19,590	42.0	177,747	9.10
25.....	11,390		11,390	10,970	44.4	173,128	15.80
26.....	16,320		16,320	15,830	33.3	139,778	8.85
27.....	20,030		20,030	19,490	40.2	175,591	9.00
28.....	14,600		14,600	14,160	59.3	251,222	17.75
29.....	20,730		20,730	19,930	54.1	192,713	9.65
30.....	17,660		17,660	17,100	41.2	173,837	10.15
31.....	13,260		13,260	12,800	37.9	151,448	11.85
32.....	4,800		4,800	4,620	12.2	56,593	12.25
Outside of districts (includes water area).....			17,590				
Total.....	539,120	59,580	611,900	530,670	1,630.3	5,598,249	10.55

¹ Timbered marsh.

CONCLUSION.

SUFFICIENCY OF THE DRAINAGE PLAN.

The various improvements for each gravity district in Jefferson County have been planned to provide every part of such districts with sufficient outlet to insure against injury from excess of water except during and immediately following extraordinarily heavy storms. The ditches are so arranged that few points will be more than a quarter of a mile from a lateral. The design provides convenient and adequate outlets for tile drains or field ditches that landowners may wish to install.

In the pumping districts the ditches are planned 1 mile apart to serve the present needs of the county, and at a later date when the lands are put under thorough cultivation additional ditches will be needed to give complete drainage. The pumping plant for each district was designed to remove the excess water promptly after heavy rainstorms, to a depth of 4 feet below the ground surface at the site of the pumping plant, when the entire district has been thoroughly ditched, although canals 1 mile apart will not carry all this excess water promptly to the pumps and therefore the drainage will be much slower under the present plan than when the additional ditches and field laterals shall have been constructed.

VALUE OF DRAINAGE IN JEFFERSON COUNTY.

The money value of drainage is not easily measured, but the cost of this work is a permanent investment which must be added to the cost of the land if the proper returns are to be obtained from the first investment. As only 10 per cent of the area is timbered, the cost of clearing will be comparatively small. The worth of drainage may be measured by the increase in land values which it produces. If the land is as fertile in Jefferson County, Tex., as in some other localities along the Gulf coast, which can easily be determined, the net increase in crop values when the land has been reclaimed may be expected to yield very profitable returns upon the cost of purchase, drainage, and any other measures necessary to put the land into cultivation. Farming operations may be conducted more economically on drained than undrained land. Rice growing is the principal industry of the county, and this requires drainage as well as irrigation. Drainage is also insurance against loss of crops by excessive wetness. Localities where malaria exists will be benefited through the removal of stagnant pools that are the breeding places for mosquitoes which spread this disease. Drainage is also necessary if the good highway system, of which Jefferson County is proud, is to be economically maintained and extended.

APPENDIX.

DITCH SIZES AND EARTHWORK.

Ditch Nos.	Length.	Width of bot- tom.	Aver- age cut.	Exca- vation.	Ditch Nos.	Length.	Width of bot- tom.	Aver- age cut.	Exca- vation.
District No. 1: 1 to 10, in- clusive....	<i>Feet.</i> 71,480	<i>Feet.</i> 2	<i>Feet.</i> 6 to 7	<i>Cu. yds.</i> 129,900	District No. 4— Continued.	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Cu. yds.</i>
A.....	18,000	50	10 to 15	165,500	13.....	{ 8,000 13,120 12,000 5,800 8,500 6,300 9,500 3,700	{ 4 2 4 2 4 2 4 2	{ 7½ to 8 6 to 7 7 to 7½ 6 to 6½ 6 to 6½ 6 to 6½ 6 to 6½ 6 to 6½	{ 54,350 46,250 31,300 28,900
Total.....				195,400	14.....	{ 16,200 2,200 4,500 11,100 7,400 2,500 7,500	{ 2 6 4 2 2 4 2	{ 6 8 7 to 8 6 to 8 6 to 8 6 to 8 6 to 8	{ 28,850 31,150 13,150 18,900
District No. 2: 1 to 5, in- clusive....	{ 40,760 3,000 2,800 2,700 6,500	{ 2 8 12 4 2	{ 6 8 7 6½ to 7 6½ to 7	{ 72,550 49,550	15.....	{ 29,700 6,000 8,600 5,500 5,000	{ 2 4 2 4 2	{ 5 to 10 6 to 8 6 to 10 6 to 10 6 to 10	{ 56,900 35,200 30,100
6.....	{ 7,600 3,500 5,700	{ 2 4 2	{ 6 6½ 6 to 7½	{ 13,550 21,150	16.....	{ 70,700 8,600 4,600 9,940	{ 2 4 2 2	{ 6 to 8 6 to 8 6 to 8 6 to 8	{ 118,900 28,600 17,700
7 to 8, in- clusive....	{ 31,700 7,000 6,200 7,000 6,800 3,500 9,500	{ 2 4 2 4 2 4 2	{ 6 to 7 6½ to 7 6 6 to 7 6 6 to 6½ 6 to 6½	{ 59,800 29,350 29,850 26,000	Total.....				761,350
9.....	{ 39,500 15,400 5,600 13,300 7,900 3,100	{ 2 30 25 20 18 2	{ 6 to 6½ 8½ to 9 8½ to 9 8½ to 9 7½ to 8 6½ to 7	{ 72,150 152,300	District No. 5: 1 to 10, in- clusive....				
10 to 13, in- clusive....					11.....				
14.....					12 and 13...				
15.....					Total.....				165,200
16.....					District No. 6:				
17 to 22, in- clusive....					1.....	{ 6,200 5,500 9,000 12,700 13,000 31,500	{ 10 12 10 30 10 10	{ 6½ to 8 6 to 7 6½ to 8½ 9 to 10½ 7 to 8 8½ to 10½	{ 29,200 25,800 43,700 243,500 212,600
A.....					Total.....				554,800
Total.....				526,250	District No. 7:				
District No. 3. ³					1.....	{ 2,800 6,500 9,700 3,200 3,500 8,600 13,500	{ 10 12 10 14 12 10 10	{ 6½ to 7 6 to 7½ 6½ to 7½ 8½ to 9 8½ to 9 7 to 8 7 to 8½	{ 11,500 32,000 43,800 104,500 68,700
District No. 4:					Total.....				260,500
1.....	{ 14,200 12,200 14,800 5,600 3,000 5,800 3,200 2,600 3,800 14,400 5,280 10,720 5,000 4,500 5,500 7,200 15,300	{ 18 2 2 2 2 2 10 6 2 2 8 4 6 4 2 2 2	{ 6 to 9 6 to 6½ 6½ to 7 6 to 6 6 to 6 7½ to 8 6 to 7½ 6 to 7½ 6 to 7 6 to 7 6 to 8½ 6 to 8½ 6 to 8½ 6½ to 8 6 to 8 6 to 6½	{ 121,150 27,500 20,200 10,300 33,700 28,000 69,100 48,450 27,900	District No. 8. ³				

¹ Willow Creek saves 458,700 cubic yards.

² Cotton Creek saves 292,400 cubic yards.

³ Plans and estimates not made by Drainage Investigations.

⁴ Trahan Gully saves 25,000 cubic yards.

⁵ Bird Gully saves 14,800 cubic yards.

⁶ Old Gully saves 3,550 cubic yards, ditch No. 1. No excavation stations 6 to 25, ditch No. 3.

⁷ Brakes Bayou saves 9,150 cubic yards.

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.	Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 9: 1 to 5 inclusive.....	<i>Fect.</i> 31,600	<i>Fect.</i> 10	<i>Fect.</i> 9	<i>Cu. yds.</i> 136,900	District No. 10— Continued.	<i>Fect.</i> 3,500	<i>Fect.</i> 4	<i>Fect.</i> 6½	<i>Cu. yds.</i> 22,050
6.....	9,000	14	8 to 9	267,700	53.....	7,100	2	6 to 6½	31,300
	12,000	12	8 to 8½		54.....	2,800	4	8 to 8½	14,200
	25,000	10	6½ to 7½		55.....	10,400	2	6 to 7½	18,850
	10,000	34	9		56.....	8,000	2	6	18,900
7.....	3,200	30	8½	420,900		2,500	4	6	24,400
	19,300	20	7½ to 8		57.....	7,500	2	6 to 6½	30,750
	13,000	10	6½ to 7		58.....	2,000	4	6 to 6½	35,050
Total.....				825,500	59.....	8,000	2	7 to 7½	39,400
District No. 10:					60.....	4,800	2	6	7,100
3.....	4,000	4	7 to 7½	24,800		9,000	4	7	35,050
	6,500	2	6 to 6½		61.....	6,500	2	6	39,400
4.....	3,000	6	7	29,800	62.....	2,400	6	6½ to 7½	7,100
	4,000	4	6½ to 7		63.....	6,100	2	6	37,200
	5,000	2	6		64.....	7,900	2	6	34,450
5 to 7 inclusive.....	14,000	2	6	24,900	65.....	4,000	2	6	26,000
8.....	3,500	4	6½ to 7	18,200	66 to 78, inclusive.....	68,580	2	6	121,850
9 to 13 inclusive.....	4,500	2	6	57,600	79.....	7,500	4	6	18,500
14.....	3,000	4	6	18,350		1,800	2	6	36,400
	6,600	2	6		80.....	10,000	2	6 to 6½	23,800
15.....	4,000	4	6 to 7	20,750	81.....	6,800	4	6	99,650
	5,600	2	6		82 to 91, inclusive.....	4,000	2	6	19,950
16.....	4,500	4	7 to 7½	25,755	92.....	6,400	2	6	21,600
	6,100	2	6 to 7		93.....	56,100	2	6	24,350
17.....	5,500	4	6½ to 7½	28,450	94.....	3,000	4	6	39,800
	6,500	2	6 to 6½		95 and 96.....	7,500	2	6	39,150
18.....	4,500	4	6½ to 7	30,150	97.....	22,360	2	6 to 7½	58,050
19.....	9,100	2	6 to 7½	29,900	98.....	8,000	4	6 to 7½	40,950
	7,000	4	6 to 8		99.....	9,600	2	6 to 7	18,800
	7,400	2	6		100.....	11,000	4	6½ to 7½	22,650
	12,100	18	8 to 10		101.....	11,200	2	6	23,750
20.....	2,900	10	8		102.....	9,000	2	6 to 6½	16,550
	7,100	8	7 to 8½		103.....	7,400	2	6	192,500
	900	4	6	157,900	104 to 122, inclusive.....	10,560	2	6	39,600
21.....	3,200	2	6		123.....	5,000	4	6 to 6½	24,550
	2,500	2	6	25,550	124 and 125.....	6,500	2	6	117,600
22.....	9,900	2	6 to 7	13,850		4,500	4	6½ to 7½	19,400
23.....	7,800	2	6	37,400	106.....	7,500	2	6 to 6½	96,800
	6,800	4	8 to 8½		107.....	9,000	2	6 to 7	19,700
24 to 32 inclusive.....	4,800	2	6 to 8	74,250	108.....	5,000	4	6½ to 7	19,150
33.....	8,000	4	6 to 6½	27,350	109.....	1,500	20	7½ to 8½	8,200
	5,400	2	6	30,600	110.....	7,900	10	6½ to 7	21,250
34 and 35.....	17,200	2	6 to 6½	28,100	111.....	3,300	2	6	12,450
36.....	8,000	4	6 to 6½		112.....	2,300	4	6	
	4,800	2	6 to 6½	25,600	113.....	7,000	2	6	
37 to 39, inclusive.....	14,400	2	6	34,650	114.....	5,000	4	6½	
40.....	9,500	4	6 to 8	28,700	115.....	3,800	2	6	
	5,100	2	6	24,000	116.....	53,380	2	6 to 6½	
41.....	7,500	4	6 to 6½	14,950	117.....	2,000	4	6 to 7½	
	6,000	2	6	16,950	118.....	7,500	2	6	
42.....	5,500	4	6 to 7	16,400	119.....	5,000	4	6½ to 7	
	5,700	2	6	35,800	120.....	3,200	2	6	
43.....	2,000	4	7	17,950	121.....	4,600	2	6	
	5,200	2	6	24,800	122.....	3,500	4	6 to 6½	
44.....	3,000	4	7	23,350	123.....	7,300	2	6	
	4,200	2	6	40,850	124.....	7,000	2	6	
45.....	3,000	4	6½ to 7	23,350	125.....	3,800	2	6	
	4,800	2	6		126.....	53,380	2	6 to 6½	
46.....	2,000	6	8 to 8½	17,950	127.....	2,000	4	6 to 7	
	8,200	2	6 to 7	24,800	128 to 137, inclusive.....	7,500	2	6	
47.....	9,800	2	6 to 6½	33,950	138.....	5,000	4	6½ to 7	
	4,000	4	6 to 6½	40,850	139.....	3,200	2	6	
48.....	8,600	2	6	23,350	140.....	4,600	2	6	
	13,500	2	6½ to 7		141.....	3,500	4	6 to 6½	
49.....	1,500	4	6		142.....	7,300	2	6	
	11,500	2	6			7,000	2	6	
50.....	6,100	2	6						
51 and 52.....	13,000	2	6 to 6½						

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bot- tom.	Aver- age cut.	Exca- vation.	Ditch Nos.	Length.	Width of bot- tom.	Aver- age cut.	Exca- vation.
District No. 10— Continued.	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Cu. yds.</i>	District No. 11— Continued.	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Cu. yds.</i>
143.....	1,400	4	6½ to 7½	15,350	14.....	5,000	4	6½ to 7	31,100
144 to 147, in- clusive.....	5,800	2	6 to 7½		15 to 18, in- clusive.....	10,000	2	6 to 6½	47,800
148.....	26,780	2	6	47,600	19.....	26,500	2	6 to 6½	24,650
149.....	6,500	4	6½ to 7	30,900	20.....	6,000	4	6 to 6½	58,700
150.....	7,500	2	6	21,550	21 to 23, in- clusive.....	5,500	2	6 to 9	22,900
151.....	3,000	4	6	16,900	24.....	15,000	2	6½ to 7½	58,350
152 to 157, in- clusive.....	8,400	2	6	14,450	25.....	7,000	2	6 to 7½	61,050
Hillebrant Bayou be- low Pivi- tot B.....	9,500	2	6	56,500	26.....	6,000	2	6½ to 7	53,550
	600	4	6		27.....	14,500	4	6 to 6½	19,600
	7,400	2	6		28.....	8,000	2	6 to 6½	21,500
	39,000	50	19	1,201,700	29 to 32, in- clusive.....	10,300	2	6 to 6½	29,300
Main A.....	13,000	18	7½ to 9½		33.....	5,000	4	7 to 7½	32,550
	4,500	16	7½ to 8	223,250	34.....	8,000	2	6 to 7½	29,600
	13,000	12	7 to 9		35.....	9,000	4	6 to 6½	26,300
	3,500	10	7½ to 8		36.....	3,000	2	6 to 6½	25,500
	3,200	8	6 to 7		37.....	5,000	4	6½ to 7	33,350
	4,500	2	6		38.....	7,000	2	6	21,250
Main B.....	12,000	70	12 to 14		39.....	5,000	14	8½	106,550
	5,500	80	10½ to 11½		40 and 41...	4,400	12	8	
	11,500	70	10 to 10½		42.....	15,600	4	6 to 8	24,500
	23,000	40	10 to 11		43 and 44...	13,000	2	6 to 7	33,800
	6,200	35	8½ to 9½		45.....	8,500	4	6½ to 7½	19,150
	2,800	25	8½ to 9	1,367,650	46.....	4,700	2	6	49,050
	4,000	20	9		47.....	10,800	2	6½ to 8	25,250
	6,700	16	9½		48.....	14,000	2	6 to 6½	52,400
	3,800	14	7½ to 8½		49.....	4,000	2	6	11,200
	3,600	12	7		50.....	7,500	4	7 to 7½	48,100
	2,900	4	6		51.....	4,300	2	6	29,200
	5,800	2	6		52.....	16,000	4	6 to 6½	30,950
	6,000	30	9 to 10		53.....	2,000	2	6½	8,900
	11,000	35	9 to 9½		54 to 57, in- clusive.....	6,300	2	6 to 7½	26,650
	11,000	16	9½ to 12½		58.....	2,200	14	8	
	10,000	18	9½ to 10½		59 to 60, in- clusive.....	2,700	12	7½ to 8	41,550
Main C.....	7,500	16	9 to 10	458,150	61.....	2,700	6	7½	34,500
	1,000	14	9		62.....	4,600	2	6	20,200
	3,700	10	9		63.....	4,000	2	6 to 7	43,400
	5,000	8	8½ to 9		64.....	14,500	4	6½ to 8	52,950
	5,800	6	6½ to 7½			5,300	2	6	
	1,600	2	6			15,000	6	7½ to 8	90,500
Main D.....	24,400	35	9½ to 13			4,000	4	7	
	2,600	20	9 to 9½			8,400	2	6½	4,800
	3,600	16	8 to 8½			2,700	2	6	
	5,500	10	8 to 8½	449,150					
	12,200	8	7½ to 8½						
	5,700	4	7 to 7½						
	6,300	2	6½						
Main E.....	16,800	6	8½ to 12	102,000					
	5,200	4	7 to 8½						
	1,500	2	6 to 7						
				6,708,700					
District No. 11:									
1 to 8, in- clusive.....	47,900	2	6 to 6½	86,100					
9.....	7,500	4	6 to 6½	31,450					
10 to 12, in- clusive.....	8,000	2	6	25,600					
13.....	14,460	2	6	170,200					
	5,500	25	9 to 9½						
	5,300	10	9 to 9½						
	3,600	8	9½ to 10						
	5,300	10	8 to 9						
	3,700	4	7½						
	3,300	2	6						

1 Including 8 cut-offs.

2 Johns Gully saves 9,000 cubic yards.

3 Hillebrant Bayou saves 395,300 cubic yards.

4 Willow Marsh Channel saves 43,650 cubic yards.

5 Bayou Din saves 108,400 cubic yards.

6 Pivotot Bayou saves 14,500 cubic yards.

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bot- tom.	Aver- age cut.	Exca- vation.	Ditch Nos.	Length.	Width of bot- tom.	Aver- age cut.	Exca- vation.
District No. 11— Continued.	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Cu. yds.</i>	District No. 11— Continued.	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Cu. yds.</i>
65.....	4,000	4	7	29,050	97.....	6,500	4	7 to 7½	33,400
66 and 67.....	9,000	2	6 to 6½	32,400		7,700	2	6 to 6½	
	17,800	2	6 to 7			10,500	6	8 to 9	
68.....	6,500	14	10	93,600	98.....	16,500	4	7 to 8½	119,850
	3,000	6	7½			9,800	2	6 to 7	
	5,500	4	7		99 to 101, in- clusive.....	16,600	2	6 to 6½	29,450
	4,500	2	6½			7,000	4	6½ to 7	28,550
69.....	9,000	14	7½ to 9	101,100	102.....	5,200	2	6	8,900
	6,000	6	6½ to 7½		103.....	5,000	2	6	22,400
	2,500	6	6½		104.....	6,500	4	6	
	4,600	2	6 to 6½			4,500	2		
70.....	4,500	6	6	28,900	105 to 109, inclusive.....	28,320	2	6 to 6½	51,450
	9,500	2	6			3,500	6	8	
71.....	3,500	4	7	31,100	110.....	7,000	4	7 to 7½	59,300
72.....	10,900	2	6 to 6½	24,050		11,700	2	6 to 7	
	11,000	2	6 to 8			5,500	6	7½ to 8½	61,200
73.....	6,000	8	7 to 7½	60,150	111.....	4,000	4	7	
	3,000	6	7			13,400	2	6 to 7	
	4,500	4	6½		112.....	9,000	6	7 to 9	77,350
74.....	7,200	2	6 to 6½	13,650		6,000	4	6½ to 7	
	4,000	4	6½			11,000	2	6 to 6½	
75.....	2,000	2	7 to 8	51,500	113 to 117, inclusive.....	25,000	2	6 to 6½	42,700
	8,000	4	6½			34,000	75	12½ to 13½	
	9,800	2	6	51,000		16,000	55	13½ to 15	
76.....	10,000	6	6½ to 7½	79,000	Main A.....	16,500	50	12 to 14	13,458,400
	9,800	2	6			26,000	45	10½ to 13	
77.....	5,700	16	9 to 10	60,100		7,500	40	10	
	13,800	2	6 to 9			3,800	30	9 to 9½	
	4,200	16	8½ to 9	21,400		16,200	25	8 to 9	
78.....	5,000	6	7 to 9	21,350		28,900	30	11 to 12½	
	5,500	2	6			18,600	25	8½ to 9	
79.....	3,500	4	6½	24,350	Main B.....	1,000	14	8	2607,250
	7,000	2	6 to 6½			7,500	4	6 to 7½	
80 and 81.....	11,700	2	6 to 6½	31,750		4,500	2	6	
	2,500	4	7			10,200	18	9 to 11	
82.....	9,000	2	6 to 6½	31,250	Main C.....	14,200	12	7 to 8½	3194,950
	5,000	4	6½ to 7½			6,600	8	7½ to 8	
83.....	9,700	2	6 to 6½	13,300		4,500	6	7½ to 8½	
	4,000	4	7			5,000	2	6 to 7	
84.....	10,700	2	6 to 6½	79,500		21,500	25	9 to 11	
	7,500	2	7 to 8½		Main D.....	3,500	20	8 to 8½	4380,650
85.....	12,000	6	6½ to 7	60,950		4,000	8	7½ to 8½	
	8,500	4	6½ to 6			30,000	4	6 to 8	
86.....	6,700	2	7 to 7½	11,350	Total.....				8,254,250
	10,000	6	6 to 6½		District No. 12:				
87.....	2,000	4	7 to 7½	166,550	1.....	4,800	2	6	8,550
	9,000	2	6 to 6½			3,200	6	8 to 9	
88.....	6,400	2	6	85,600	2.....	3,000	4	7½ to 8½	38,850
	9,100	14	8 to 9			7,600	2	6	
89.....	8,100	12	8	13,450	3 to 9, inclu- sive.....	33,900	2	6	60,300
	3,800	10	7 to 7½	19,550		7,000	4	6½	24,650
	3,200	8	7 to 7½		10.....	3,500	2	6	16,800
	10,400	2	6 to 6½		11 and 12.....	9,440	2	6	25,950
90.....	3,000	8	8 to 8½	7,800	13.....	5,000	4	6½	
	7,000	6	8			7,500	2	6	
	8,800	4	7½ to 8			4,000	6	7 to 8	
	5,700	2	6 to 7		14.....	3,000	4	7 to 7½	35,500
91.....	7,200	2	6 to 7	75,000		6,500	2	6	
	4,000	4	6½		15 to 17, in- clusive.....	20,000	2	6 to 7	37,600
92.....	5,000	2	6 to 6½			1,900	6	7 to 7½	31,300
	4,500	4	6 to 6½		18.....	12,300	2	6 to 7	
93.....	4,700	2	6		19 to 27, in- clusive.....	49,980	2	6 to 6½	88,350
94.....	4,400	2	6						
95.....	10,000	6	8 to 8½						
	6,500	4	6½ to 7½						
	7,700	2	6						
	1,100	10	8						
96.....	12,900	6	6½ to 8						
	11,800	2	6 to 6½						

1 Taylors Bayou saves 75,000 cubic yards excavation main A.

2 Old ditch saves 148,000 cubic yards excavation main B.

3 Old ditch saves 47,500 cubic yards excavation main C.

4 Taylors Bayou saves 48,800 cubic yards excavation main D.

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bot- tom.	Aver- age cut.	Exca- vation.	Ditch Nos.	Length.	Width of bot- tom.	Aver- age cut.	Exca- vation.
District No. 12 Continued.	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Cu. yds.</i>	District No. 14 Continued.	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Cu. yds.</i>
Main A. {	6,000	10	0 to 10 $\frac{1}{2}$	134,800	30. {	4,500	10	7	51,900
	10,900	6	9 to 10			3,500	7	6 $\frac{1}{2}$	
	8,600	4	6 $\frac{1}{2}$ to 8 $\frac{1}{2}$			5,000	4	6	
	4,000	2	6			5,000	2	6	
Total. {				502,050	31 and 32. {	14,200	2	6 to 7	30,250
District No. 13:						25,000	45	10 $\frac{1}{2}$ to 11 $\frac{1}{2}$	681,000
1 to 10, in- clusive. {	48,680	2	6	86,550	Main A. {	15,800	25	9 to 9 $\frac{1}{2}$	
11. {	1,400	4	7 $\frac{1}{2}$	16,350		3,600	10	8 to 8 $\frac{1}{2}$	
12 to 19, in- clusive. {	6,400	2	6 to 6 $\frac{1}{2}$	82,250		1,600	8	8	
20. {	46,000	2	6 to 6 $\frac{1}{2}$	24,200		7,000	4	7	185,050
21 to 25, in- clusive. {	5,000	4	6 to 6 $\frac{1}{2}$	38,250	Main B. {	3,000	2	6	
26. {	6,500	2	6	32,050		2,500	40	10	
27. {	21,500	2	6	33,250		5,000	18	9 to 9 $\frac{1}{2}$	
	5,500	4	6 $\frac{1}{2}$ to 7	32,050		12,000	12	8 to 8 $\frac{1}{2}$	326,850
	8,500	2	6 to 7			5,800	2	6 to 7 $\frac{1}{2}$	
28. {	8,000	4	6 $\frac{1}{2}$ to 7 $\frac{1}{2}$	180,600		17,500	32	8 $\frac{1}{2}$ to 9 $\frac{1}{2}$	
	7,000	2	6		Main C. {	4,500	16	8 $\frac{1}{2}$ to 9	
29. {	12,500	16	9 $\frac{1}{2}$	8,200		3,500	12	8 $\frac{1}{2}$	326,850
	5,500	14	7 $\frac{1}{2}$ to 8			5,000	8	7 to 7 $\frac{1}{2}$	
	3,000	12	7	535,650	Total. {	7,400	2	6 to 7 $\frac{1}{2}$	1,863,200
	7,500	6	7 to 7 $\frac{1}{2}$		District No. 15:				
	4,600	2	6	1,037,350	1 to 7, in- clusive. {	32,300	2	6 to 6 $\frac{1}{2}$	57,900
	15,800	32	10 to 11		Main A. {	4,100	6	8 $\frac{1}{2}$ to 9 $\frac{1}{2}$	45,850
	6,700	25	8 to 9 $\frac{1}{2}$	535,650		3,900	4	7 $\frac{1}{2}$ to 8	
	14,200	20	8 to 9		Total. {	5,500	2	6 to 8	103,750
Main A. {	3,700	18	8	535,650	District No. 16:				253,350
	2,900	14	7 $\frac{1}{2}$		1 to 5, in- clusive. {	55,500	10	6 $\frac{1}{2}$ to 8	
	3,200	8	7 $\frac{1}{2}$	1,037,350	6 to 10, in- clusive. {	37,100	2	6 to 7 $\frac{1}{2}$	72,400
Total. {	7,700	2	6 to 6 $\frac{1}{2}$			4,700	10	7 $\frac{1}{2}$	37,500
District No. 14:					11. {	7,100	2	6 to 7	29,900
	5,000	10	8 $\frac{1}{2}$ to 9 $\frac{1}{2}$	70,850	12. {	5,300	6	7 to 8 $\frac{1}{2}$	42,950
1. {	2,500	8	8			5,260	2	6	16,800
	2,800	4	6 $\frac{1}{2}$ to 7 $\frac{1}{2}$	11,350	13 and 14. {	21,100	2	6 to 6 $\frac{1}{2}$	20,450
	4,500	2	6		15. {	1,500	10	7	434,600
2. {	6,400	2	6	47,550		5,500	2	6 to 6 $\frac{1}{2}$	
	5,000	6	7 to 7 $\frac{1}{2}$	45,600	16 and 17. {	11,100	2	6 to 6 $\frac{1}{2}$	72,850
3. {	2,500	4	7 $\frac{1}{2}$ to 8 $\frac{1}{2}$			9,000	34	9	
	8,900	2	6 to 9 $\frac{1}{2}$	31,550	18. {	6,000	24	8 $\frac{1}{2}$	980,800
	5,500	6	7 to 7 $\frac{1}{2}$			10,000	20	8 to 8 $\frac{1}{2}$	
4. {	6,500	4	6 to 7 $\frac{1}{2}$	20,550		22,500	10	6 $\frac{1}{2}$ to 8	135,200
	4,300	2	6			4,500	12	9	
	1,500	7	7	27,250	Main A. {	1,500	10	8 $\frac{1}{2}$	563,100
5. {	2,500	6	7			4,500	6	8	
	2,500	4	6 $\frac{1}{2}$	20,550	Total. {	6,300	2	6 to 7	980,800
	6,500	2	6		District No. 17:				
6. {	2,000	4	6 $\frac{1}{2}$	27,250		20,900	28	8 $\frac{1}{2}$ to 9 $\frac{1}{2}$	313,150
	8,300	2	6		1. {	7,100	20	7 $\frac{1}{2}$ to 8	
7. {	7,500	4	6 to 7	118,250		8,500	10	6 $\frac{1}{2}$ to 7	135,200
	4,000	2	6		2 to 6 inclu- sive. {	29,100	10	6 $\frac{1}{2}$ to 8	
8 to 21, in- clusive. {	68,720	2	6	16,950	7. {	8,800	12	6 to 7	38,000
	2,200	4	7		8. {	11,000	8	7 $\frac{1}{2}$ to 8 $\frac{1}{2}$	52,750
22. {	6,000	2	6 to 6 $\frac{1}{2}$	25,000	9. {	6,000	12	6	24,000
	2,500	4	7		Total. {				563,100
23 to 25, in- clusive. {	24,000	2	6 to 6 $\frac{1}{2}$	17,950	District No. 18:				51,200
	10,000	2	6 to 6 $\frac{1}{2}$		1. {	12,800	12	6	
26. {	8,200	2	6 to 7	29,350	2. {	13,000	10	6 $\frac{1}{2}$ to 8	57,850
	8,500	4	7			15,000	12	8 $\frac{1}{2}$ to 9 $\frac{1}{2}$	
27. {	3,500	2	6 to 6 $\frac{1}{2}$	80,900	3. {	17,500	10	6 $\frac{1}{2}$ to 8	187,500
	9,000	12	7 $\frac{1}{2}$ to 8						
28. {	2,500	8	7	80,900					
	2,500	6	7						
29. {	3,000	4	6 $\frac{1}{2}$	80,900					
	5,000	2	6						

¹ Burrells Gully saves 8,300 cubic yards excavation main A.² Rodair Bayou saves 10,700 yards excavation main A.³ Alligator Bayou saves 136,650 yards excavation main A.

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bot- tom.	Average cut.	Exca- vation.	Ditch Nos.	Length.	Width of bot- tom.	Average cut.	Exca- vation.
District No. 18— Continued.	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Cu. yds.</i>	District No. 21— Continued.	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Cu. yds.</i>
4.....	30,000	14	7½ to 9½	255,800	10.....	3,960	12	6	15,850
	10,000	10	7½ to 8		11 to 13, in- clusive.....	15,000	10	6½	59,700
	3,300	8	6½	259,600	14.....	5,000	12	6½	24,900
5.....	10,000	18	8½ to 9		15 to 18, in- clusive.....	23,000	10	6½ to 7½	116,750
	30,000	10	6½ to 8	276,850	19.....	8,000	6	9 to 9½	43,750
	10,000	32	8		20.....	35,400	12	6 to 8	171,500
6.....	10,000	25	7 to 7½	50,000	Main A.....	20,000	20	7½ to 9½	208,200
	14,700	10	6½ to 7			9,000	10	6½ to 7	
7 and 8.....	10,000	16	6	74,700	Main B.....	30,000	20	7½ to 10	372,500
9 to 11, in- clusive.....	15,000	14	6½			18,200	10	7	
12.....	5,000	12	6½ to 7½	26,050	Total.....				1,301,700
13.....	9,000	14	6 to 8	48,400	District No. 22:				
Main A.....	7,000	28	9½	158,500	1 and 2.....	11,400	10	6½ to 7½	48,300
	13,000	10	6½ to 9		3 and 4.....	20,000	12	4 to 8½	96,350
Total.....				1,446,450	5.....	6,200	10	6½ to 7½	31,950
District No. 19:					6.....	3,500	12	6½ to 7	56,400
1.....	4,400	10	6½ to 7½	20,300	7 and 8.....	17,700	12	4 to 8	82,700
2.....	4,000	12	6½ to 7	18,300	9 and 10.....	8,100	10	6½ to 8	39,100
3 to 5, inclu- sive.....	23,000	10	6½ to 8	96,940		5,000	20	9½	350,600
6.....	5,000	12	6½ to 7	22,500	11.....	15,000	18	8½ to 9	
7.....	4,100	10	6½	16,300		15,000	14	7½ to 8	96,800
Main A.....	30,000	16	7½ to 9½	227,400		11,500	10	6½ to 7	
	6,500	8	6½ to 7		12.....	10,000	14	7½ to 8	298,400
Total.....				401,740		7,500	10	6½ to 7	
District No. 20:					Main A.....	11,000	22	9½ to 10	298,400
1 to 3, inclu- sive.....	20,000	2	6 to 7	37,800		15,500	16	5 to 9	
	9,000	6	7 to 7½	46,950	Total.....	9,500	8		1,100,600
4.....	3,000	4	6½		District No. 23:				
	4,000	2	6	32,300	1.....	18,000	10	6½ to 8	85,100
5.....	6,000	4	6½ to 9½			35,000	25	7½ to 9½	378,800
	5,900	2	6	34,400	2.....	12,000	10	6½ to 7	
6.....	10,000	4	6 to 7½		3.....	8,000	10	6½ to 8	37,250
	3,800	2	6	38,300	4.....	20,000	14	7½ to 8½	216,100
7.....	11,000	4	6 to 8			19,000	12	6 to 7	
	3,700	2	6	41,150	5.....	10,000	16	7½ to 8	150,500
8 to 10, in- clusive.....	19,400	2	6 to 8			10,000	14	6½ to 7	
11.....	2,000	4	6 to 7	21,600		6,000	12	6	190,400
	7,100	2	6 to 7½		6 to 9, inclu- sive.....	41,500	10	6½ to 8	
12.....	4,000	4	6½ to 7½	25,250	10.....	7,800	12	6½ to 7	35,050
	6,800	2	6 to 7	27,200	11 to 16, in- clusive.....	24,000	10	6½	95,850
13.....	3,500	4	6 to 7			2,000	30	10	264,000
	8,500	2	6 to 7½	25,000	Main A.....	10,600	18	9 to 10	
14.....	5,000	4	6 to 6½			20,400	10	8 to 9	1,453,050
	7,000	2	6½ to 7	25,800	Total.....				
15.....	5,000	4	6½ to 7		District No. 24:				
	7,000	2	6	32,850		5,000	18	9	136,300
16.....	6,000	4	6 to 6½		1.....	5,000	16	8	
	6,500	4	6½ to 7	68,550		10,500	10	6½ to 7	164,550
17.....	5,500	2	6 to 8		2.....	5,000	16	8½	
	11,500	4	8	59,300		10,000	14	7½ to 8	155,300
18.....	12,000	2	6 to 7½			8,500	12	7 to 9	
19.....	20,000	4	6 to 7½	94,100		5,500	10	6	126,000
	3,500	2	6		3.....	9,000	16	7½ to 8½	
Main A.....	8,700	12	8½ to 9½	151,900		6,000	14	6½ to 7	112,900
	6,300	4	7½ to 8½			11,500	12	6	
	5,000	2	6 to 7	824,800	4.....	10,000	14	7½ to 8	97,500
Mains B and C.....	26,400	10	7½ to 9			14,000	10	6½ to 7	
Main D.....	40,000	35	10 to 10½	1,615,850	5.....	10,000	14	7½ to 8	79,700
Total.....						11,500	10	6½ to 7	
District No. 21:						5,000	16	7½	36,400
1 to 4, inclu- sive.....	30,000	10	6½ to 8½	151,800	6.....	10,000	14	6½ to 7	
5 to 8, inclu- sive.....	26,460	12	6 to 7	121,000		3,500	12	6	36,400
9.....	3,960	10	6½	15,750	7.....	13,000	16	6½ to 7	
						3,000	12	6	36,400
					8 and 9.....	19,000	12	6 to 6½	

[illegible]

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bot- tom.	Aver- age cut.	Exca- vation.	Ditch Nos.	Length.	Width of bot- tom.	Aver- age cut.	Exca- vation.
District No. 30:	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Cu. yds.</i>	District No. 31:	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Cu. yds.</i>
1 to 3, inclu- sive.....	24,100	12	6 to 9	110,400	1.....	5,000	16	8½ to 9½	97,050
4.....	4,500	18	8½ to 9	94,250	2.....	2,500	14	7½	
	3,500	16	7½ to 8			7,600	10	6½ to 7	63,650
	2,000	14	6½ to 7	78,800	3.....	4,500	16	7½ to 8½	
	4,500	12	6			6,500	10	6½ to 7	48,400
	2,500	16	8½	49,550	4.....	4,000	16	7½ to 8½	
	4,500	14	7½ to 8			6,000	10	6½ to 7	40,900
	6,500	10	6½ to 7	46,750	5 to 11, in- clusive...	9,300	10	6½ to 7½	
	14,500	12	5 to 6			36,000	12	6 to 7	122,900
	1,000	20	5	66,600	12.....	3,500	10	6½ to 7	14,550
	2,000	18	7			1,000	16	8½	43,800
	5,500	12	6	65,900	13.....	3,000	14	7½ to 8	
	2,500	16	7½ to 8			3,300	10	6½ to 7	6,400
	2,500	14	6½ to 7	63,600		3,000	14	8½ to 9	
	7,500	12	6			4,000	12	7½ to 8	227,150
	5,500	16	6½ to 7	124,400		4,200	10	6½ to 7	
	7,000	12	6			15,000	16	8½ to 9½	493,100
	10,000	14	6½ to 7	623,700		15,000	14	6½ to 7½	
	2,000	12	6			4,500	12	6	1,254,950
11 and 12....	29,700	12	6 to 7	194,100		6,000	32	10	
	7,400	50	10		Main A.....	5,200	26	9½	365,150
	5,800	48	9½	1,502,050		5,300	22	8½	
	14,500	42	6 to 9½			45,500	16	6½ to 8	
Main A.....	3,100	30	6 to 8½	194,100	Total.....				
	5,700	25	8½						
	5,700	14	8	121,000	District No. 32:				
	4,800	8	7½		1 to 4, inclu- sive.....	49,200	10	6½ to 9½	
	6,700	16	9½	121,000	Main A.....	15,000	14	8 to 9½	
Main B.....	13,300	12	7½ to 9		Total.....				
	9,000	10	6½						
Total.....									

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- Proposed Drainage District Numbers.....
- Proposed Ditches.....
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- Proposed Channel Improvements.....
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- Bluffs.....
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- Irrigation Canals.....
- Property Lines and Names.....
- Present Bottom Elevations.....
- Proposed Pumping Plants.....
- Timber Boundaries.....

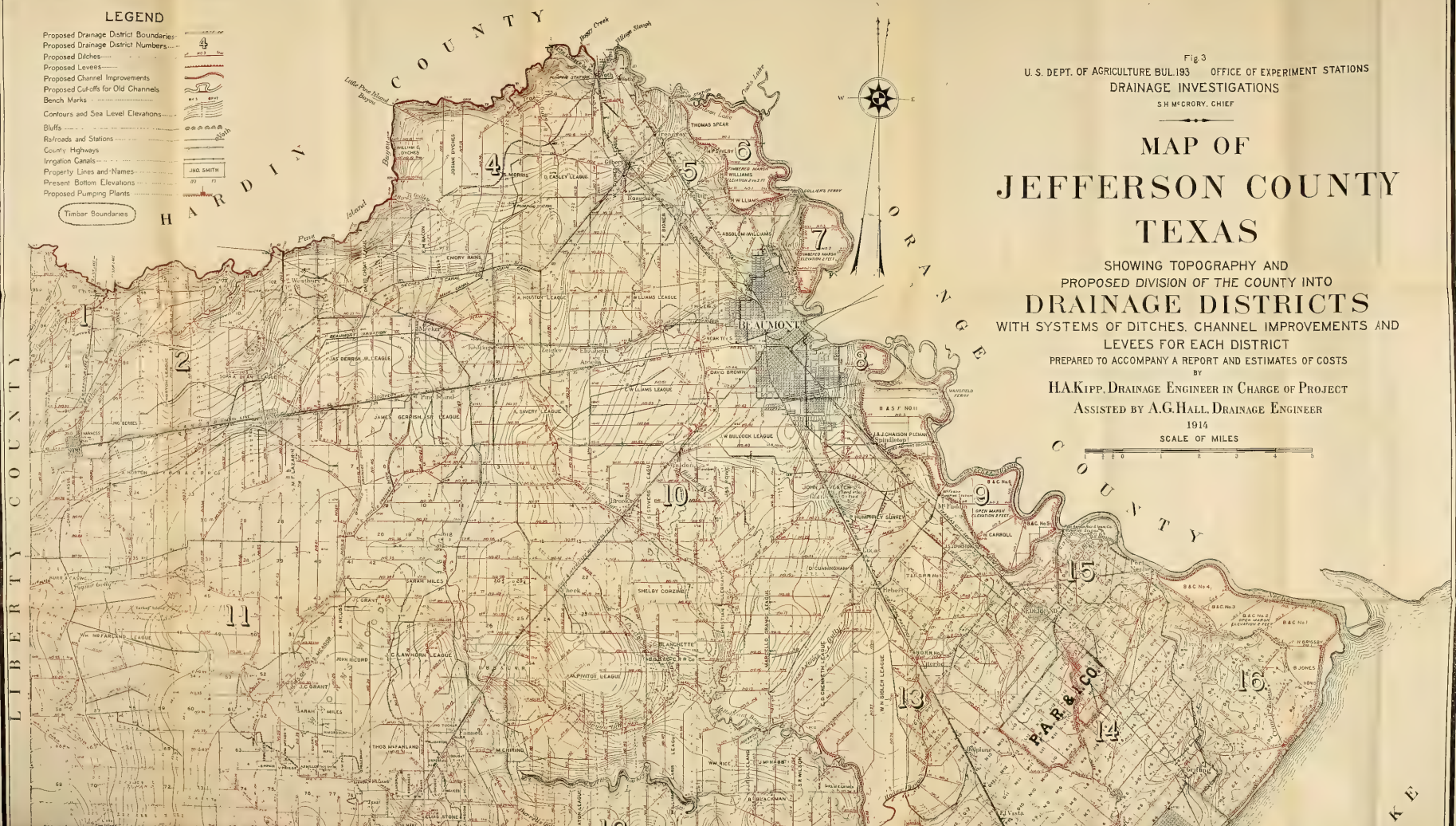
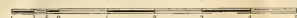


Fig 3
U. S. DEPT. OF AGRICULTURE BUL. 193 OFFICE OF EXPERIMENT STATIONS
DRAINAGE INVESTIGATIONS
S. H. McCORMY, CHIEF

MAP OF JEFFERSON COUNTY TEXAS

SHOWING TOPOGRAPHY AND
PROPOSED DIVISION OF THE COUNTY INTO
DRAINAGE DISTRICTS
WITH SYSTEMS OF DITCHES, CHANNEL IMPROVEMENTS AND
LEVEES FOR EACH DISTRICT
PREPARED TO ACCOMPANY A REPORT AND ESTIMATES OF COSTS
BY
HAKIPP, DRAINAGE ENGINEER IN CHARGE OF PROJECT
ASSISTED BY A. G. HALL, DRAINAGE ENGINEER
1914

SCALE OF MILES



C H A M B E R S C O U N T Y

(ORGANIZED)

G U L F O F M E X I C O

SABINE L.
LOUISIANA



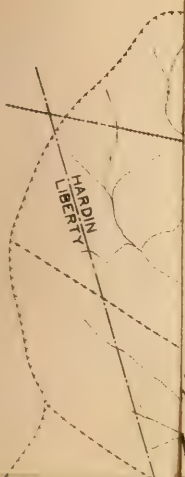


Fig. 2
BUL. 193—OFFICE OF EXPERIMENT STATIONS
WATER INVESTIGATIONS

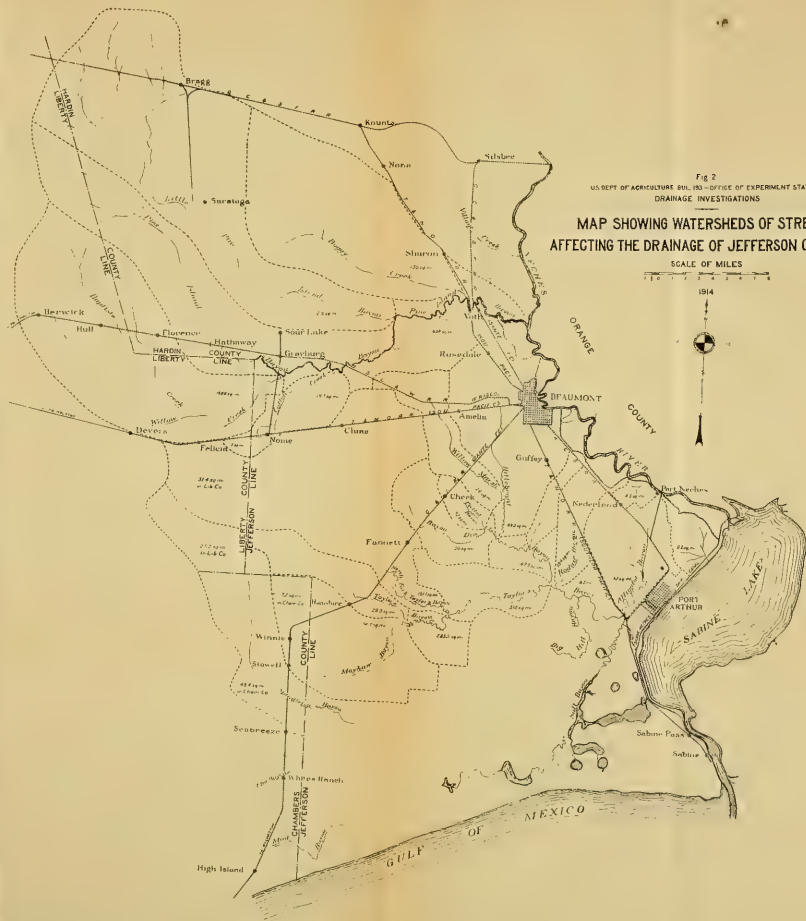
WATERSHEDS OF STREAMS

Fig 2
 U.S. DEPT. OF AGRICULTURE BULL. 193—OFFICE OF EXPERIMENT STATIONS
 DRAINAGE INVESTIGATIONS

MAP SHOWING WATERSHEDS OF STREAMS AFFECTING THE DRAINAGE OF JEFFERSON CO. TEXAS

SCALE OF MILES
 1 2 3 4

1914



UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 194

Contribution from the Office of Experiment Stations
A. C. TRUE, Director

Washington, D. C.

PROFESSIONAL PAPER

May 10, 1915

THE
FLOW OF WATER IN IRRIGATION
CHANNELS

By

FRED. C. SCOBAY, Irrigation Engineer

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Nomenclature	2	The Use of Values of n	45
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INTRODUCTION.

Irrigation systems are designed with the object in view of supplying certain quantities of water to the soil. These predetermined quantities of water must be carried in certain definite channels—of earth, wood, concrete, steel, or other material. Very often the same canal will include channels of all the above materials. Obviously channels in the smoother materials will convey water with less retardation than those in rougher ones. In order to proportion correctly the size of the channel in any given material, the extent to which the flow of water will be retarded by the character of the channel and other conditions must be known. Since this knowledge can come only through actually measuring the flow in channels under known conditions, it follows that the greater number of tests there are available the more definite is the information at the service of the engineer designing canals.

NOTE.—This bulletin treats of the subject of flowing water in irrigation channels. It is based on field tests made for the purpose of determining the retardation factor in Kutter's formula under the various conditions found in practice. The data secured are intended to aid in the design and construction of irrigation and similar channels. This publication is offered for use of engineers designing and measuring irrigation, drainage, and power channels, and for courts and attorneys at law interested in cases involving the carrying capacities of open channels.

In all English-speaking and in many other countries open channels are quite generally designed by the use of Kutter's formula. This formula was derived from such tests, but for the most part under other than irrigation conditions and before some of the now more commonly used materials of construction were generally available.

For the purpose of enlarging the number of tests under irrigation conditions, made by comparable methods, the experiments described in the body of this publication were carried out. For the sake of comparison, and where sufficient cases covering certain conditions were not found, recent tests from other sources are included in the summary table (see p. 19) of the results, and brief descriptions are given in the Appendix.

NOMENCLATURE.

Throughout this publication the following symbols will be used to designate the same element:

A.—The mean area of the water cross section throughout the length of reach tested, in square feet.

a.—The area of any particular water cross section, in square feet.

L.—The length of reach tested, in feet.

h.—The fall of the water surface in the reach tested, in feet.

P.—The mean length of the wetted perimeter throughout the reach tested, in feet.

p.—The length of the wetted perimeter at any particular cross section, in feet.

Q.—The mean discharge of the channel during the test, in cubic feet per second.

R.—The mean value of the hydraulic radius throughout the reach tested, equal to

$\frac{A}{P}$, in feet.

r.—The value of the hydraulic radius at any particular cross section, equal to

$\frac{a}{p}$, in feet.

s.—The hydraulic grade or slope of the water surface, equal to $\frac{h}{L}$, corrected for any change in the mean velocity head, in feet per foot of length in the reach.

V.—The mean velocity of the water throughout the reach tested, in feet per second.

v.—The mean velocity at any particular cross section, in feet per second.

n.—The coefficient of retardation, in Kutter's formula.

C.—The coefficient of retardation, in Chezy's formula.

HISTORICAL.

In 1775, Chezy, a French engineer, advanced the following formula for the flow of water in channels:

$$V = C\sqrt{R}s \quad (1)$$

This formula takes account of the fact that the velocity of water flowing in a uniform channel does not increase for each succeeding second of its passage as would be the case if it followed, unhindered, the law of gravity, but that it acquires a certain velocity early in its

flow and from that time the velocity remains quite constant so long as the surrounding conditions are not changed. The tendency for the velocity to increase is just counteracted by the various retarding influences.

The coefficient C was supposed to care for all of the various factors affecting the velocity, such as friction between the moving filaments of water and the containing channel, but did not involve the slope and the mean hydraulic radius.

At the present time the Chezy formula is, for the most part, used as a basis for the design of pipes and other closed conduits, while in the formula used for the design of open channels the value of C is elaborated as follows:

$$C = \frac{\frac{1.811}{n} + 41.66 + \frac{0.00281}{s}}{1 + \left\{ 41.66 + \frac{0.00281}{s} \right\} \frac{n}{\sqrt{R}}} \quad (2)$$

Substituting this value in formula (1) we have Kutter's formula, expressed in English measures:

$$V = \left\{ \frac{\frac{1.811}{n} + 41.66 + \frac{0.00281}{s}}{1 + \left[41.66 + \frac{0.00281}{s} \right] \frac{n}{\sqrt{R}}} \right\} \sqrt{R s} \quad (3)$$

In this form the formula takes into consideration the influence of hydraulic grade and of the mean hydraulic radius upon the coefficient C and introduces a new variable, n , which is supposed to represent all the retarding influences.

In its elaborated form the above formula represents a vast amount of mathematical plotting and deduction by Wilhelm R. Kutter (1818-1888), aided by E. Ganguillet, both engineers in Berne, Switzerland.¹ It was developed in 1869 from the data covering 81 different gaugings of rivers and canals, ranging from channels a few inches in width to the Mississippi River.

In the use of this formula for the design of channels in which to convey water all of the variables are determined by the materials encountered, the location of the channel, and the form chosen with the exception of n , the factor representing the retarding influences. There is a wide range of values which may be assigned to this factor, the friction becoming greater in passing from smooth, planed boards through a list of such materials as concrete, masonry, and earth in good condition to channels choked with grass, moss, and detritus.

¹ E. Ganguillet and W. R. Kutter, translated by Rudolph Hering and John C. Trautwine, Jr. *A General Formula for the Uniform Flow of Water in Rivers and other Channels*. New York, 1907, 2d ed.

NECESSARY FIELD DATA FOR VALUES OF n .

The labors of Kutter and his colleague were devoted to the development of a formula from the field experience of other engineers. Taking his formula as a basis, the later authors have made deductions from the tests of their predecessors and such experiments as they themselves conducted.¹

The tests of any one experimenter have for the most part been confined to one part of the country, and each one has secured the necessary field data by methods differing more or less from those pursued by the others. The hydraulic elements to be determined in the field are, however, essentially the same.

As previously stated, n is the one factor not easily and assuredly determined in office estimates of canal design. Therefore the field data must be secured with a view to solving the equation in Kutter's formula, with the value of n as the desired answer.

For the sake of brevity in computation, in formula 3, on page 3, let $B = k + \frac{m}{s}$, where k is 41.66 and m is 0.00281, and let $e = 1.811$, while C is the Chezy coefficient, equal to $\frac{V}{\sqrt{R s}}$.

Then in formula 3, page 3.

$$n = \sqrt{\frac{e\sqrt{R}}{BC} + \frac{1}{4}\left(\frac{C-B}{BC}\right)^2 R} - \frac{1}{2}\left(\frac{C-B}{BC}\right)\sqrt{R} \quad (4)$$

None of the variables entering the solution of this equation are directly obtained in the field, although computed from field measurements. The mean area, A , and the mean wetted perimeter, P , are matters of office computation. The hydraulic radius, R , equals $\frac{A}{P}$.

In the field the length of reach chosen is divided into several equal parts, the more the better. At the ends of the reach and at the dividing planes of the various parts sufficient soundings are made at measured distances apart, so that the cross-sectional area may be found.

Beginning at one bank of the canal, assume the soundings to be made the same distance apart, x , and calling the soundings d_0 , d_1 , d_2 ,

¹ P. J. Flynn. *Irrigation Canals and Other Irrigation Works*. San Francisco, 1892.

Samuel Fortier. *Conveyance of Water in Irrigation Canals, Flumes, and Pipes*. U. S. Geol. Survey, Water-Supply and Irrig. Paper 43 (1901).

C. C. Williams. *Notes on the Flow of Water in Irrigation Ditches*. Univ. Colo. Studies, 7 (1910), No. 4, p. 237.

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V. M. Cone, R. E. Trimble, and P. S. Jones. *Frictional Resistance in Artificial Waterways*. Colorado Sta. Bul. 194 (1914).

J. B. Lippincott. *Observations to Determine the Value of C and n as Used in the Kutter Formula*. *Engin. News*, 57 (1907), No. 23, p. 612.

. d_N , then the area at that particular cross section is expressed as follows:

$$a = Nx \left(\frac{d_0 + 2d_1 + 2d_2 + \dots + 2d_{N-1} + d_N}{2N} \right) \quad (5)$$

Note that the end soundings are given but one-half the weight assigned to the interior soundings, for the reason that their influence, in considering the average, extends over but half the distance covered by the interior soundings. A similar reasoning applies to the two following formulas.

Assuming the reach of canal tested to be divided into M equal sections and the areas $a_0, a_1, a_2, \dots, a_M$ found as by formula 5, then the mean area of the water cross section throughout the reach is as follows:

$$A = \frac{a_0 + 2a_1 + 2a_2 + \dots + 2a_{M-1} + a_M}{2M} \quad (6)$$

The lengths of the wetted perimeters at a_0, a_1, a_2 , etc., are found either by computation or by plotting each cross section on a large scale and measuring the length by scale of the line of contact between the water and the containing channel. Letting $p_0, p_1, p_2, \dots, p_M$ be the lengths of the various wetted perimeters for the corresponding areas $a_0, a_1, \dots, a_M$, then

$$P = \frac{p_0 + 2p_1 + 2p_2 + \dots + 2p_{M-1} + p_M}{2M} \quad (7)$$

and, by definition

$$R = \frac{A}{P} \quad (8)$$

Thus the field data for the determination of the term R in formula 8 consist of soundings or their equivalent with attendant horizontal measurements to determine the mean values of A and P throughout the reach tested.

The hydraulic grade is taken as the slope of the water surface in the reach of canal tested, corrected for any appreciable change in the mean velocity of the water at the two ends of the reach. If the cross sections develop the fact that the mean velocity at the upper end of the reach is less than that at the lower end, then the difference between the velocity heads necessary to create the velocities at the two ends of the reach must be deducted from the actual fall of the water surface in the reach tested. If the velocity at the lower end is less than that at the upper end, then the lost velocity head, in addition to the surface fall, has been used to overcome the retarding influences.

The general equation for the slope, including this correction is

$$s = \frac{h - (h_{v2} - h_{v1})}{L} \quad (9)$$

where h_{v2} equals the velocity head, in feet, necessary to create the mean velocity at the lower end of the reach, and h_{v1} equals the velocity head of the mean velocity at the upper end of the reach, while s , h , and L have the same significance as shown on page 2. For example, involving this correction see page 15.

In addition to the cross sections spoken of above, the field data necessary to determine the hydraulic grade is an accurate determination of the length of the reach, L , in feet and of the difference in elevation, or fall, h , in the surface of the water between the upper and the lower ends of the reach, in feet.

By far the greatest opportunity for error lies in the determination of the fall. In order to obviate inaccuracies due to slight local changes of surface slope a reach should be chosen of sufficient length that a fair average surface slope may be determined, yet it should not be so long that distinct changes in grade may greatly change the mean velocity throughout the reach. In the experiments conducted by the writer and his associates 1,000 feet was assumed as a fair length to be tested. It is impracticable to make an extended series of measurements and install the equipment necessary to carry a water level through pipes between the two ends of the reach, therefore, whatever method is used for the actual determination of the level of the water surface at the ends of the reach, the difference in elevation between the bench marks at the ends must be determined with a spirit level.

The error will approximate a constant quantity for a given length. Assume an allowable error in feet for careful work of $0.017\sqrt{\text{distance in miles.}^1}$ For length of reach of 1,000 feet the allowable error would thus be 0.0074 feet. A grade of 0.0074 per 1,000 feet would be 0.04 foot per mile. The allowable error for a reach 1,000 feet long would thus be 4 per cent of the grade of a canal having a fall of 1 foot per mile. The error in the determination of the surface slope thus has a great deal more influence on the value of n for low gradients (used in connection with large canals in earth sections) than it does for the steep gradients commonly used for irrigation canals.

The value of V , the velocity, in feet per second, is found by the formula

$$V = \frac{Q}{A} \quad (10)$$

The discharge, Q , in cubic feet per second, is determined by a direct measurement in the field, by weir or current meter. The discharge,

¹ Precise Leveling. In Topographic Instructions of the U. S. Geological Survey, 1913, p. 100.

of course, remains the same throughout the reach tested, but as a rule the mean area, A , is not identical with the area at the place where the discharge was measured, so V will not necessarily be the same as the mean velocity at the section where the discharge was measured.

The other field data to be taken in order to make the resulting value of n fully comprehensible is a careful description of the material forming the containing channel, including such growths as affect the flow of the water and a description of the influence of all structures in the canal and all changes in alignment throughout the reach tested. This general description should not only cover just the reach tested, but should extend up and down stream for sufficient distances to cover anything influencing the flow within the reach.

Temperatures of the air and water may be taken, but it is doubtful if any deductions may be made as to the direct influence of the various temperatures on the flow of water in the usual more or less irregular channel.

SCOPE OF EXPERIMENTS.

Tests were made on channels in Nebraska, Colorado, Utah, Idaho, Oregon, Montana, California, Arizona, Texas, and Louisiana. These channels ranged in size from small ditches carrying less than 1 second-foot up to canals carrying over 2,600 second-feet. The containing materials of these channels comprise wood, concrete, earth, rubble masonry, cobblestones, and a few special combinations. The velocities encountered extend up to about 10 feet per second. From other sources the writer has obtained the data for additional tests, where in his opinion there was not sufficient evidence in our own experiments from which to draw conclusions. This is particularly true of steel flumes, as none of these visited by members of this force was carrying water at the time. The data covering very high velocities, such as are found in chutes, also came from outside sources. In several cases it was possible to get data covering several tests on exactly the same reach of channel, with varying discharges of water, with a view to proving or disproving the theories of some writers who have contended that the value of n diminishes as the discharge increases, in proportion to some function of the latter, such as the velocity, the hydraulic radius, or the square root thereof.

EQUIPMENT AND METHODS EMPLOYED FOR COLLECTING FIELD DATA.

In order to weigh correctly any new data advanced which tend either to corroborate or to change existing elements in a standard formula it is necessary to know in detail the instruments employed and the methods of taking field measurements. Consequently, the equipment used and the steps pursued in developing the values of n for irrigation canals for various conditions are discussed in some detail in the following paper. The equipment and the methods described

were those used by the writer and his assistant, Mr. Ernest C. Fortier. Where those used by his associates were essentially different, the fact is mentioned.

EQUIPMENT.

Tapes.—Linear measurements for length of canal tested were made with a high-grade steel tape, 100 feet long, graduated to tenths of a foot. This tape was also used to determine widths for current-meter measurements for canals more than 25 feet wide and cross-section data for canals more than 50 feet wide. For canals under 25 feet in width the measurements of widths in determining the discharge were made with a small steel tape, 25 feet long, graduated to hundredths of a foot. For taking cross sections on canals less than 50 feet in width a 50-foot cloth tape containing strands of wire was used.

Level.—The writer used a new 18-inch Berger engineer's wye level, equipped with a bubble whose sensibility was rated at 10 seconds of arc for 1 division of scale equal to one-tenth of an inch. The bubble vial was 6.5 inches long. The telescope power was 35 diameters.

Rod.—A new Philadelphia rod, equipped with rod level and with vernier reading to thousandths of a foot was used in the determination of the fall between the bench marks at the upper and lower ends of the reach tested.

Current meters.—Two new small Price cup current meters were used. They were identical in construction, of the combination type; that is, each meter was so equipped that a single or a penta head could be used. The single head records each revolution of the meter and is adapted to water flowing up to about 5 feet per second. The penta head records each fifth revolution of the turbine and is used in high velocities. Both of these meters were rated on both rod and cable by the United States Bureau of Standards at Chevy Chase Lake, Md. They were carefully rated, as it was understood that they would be used for research work. One of these meters was used constantly, throughout the summer, the other one being very carefully cared for and rated against the one in constant use at intervals throughout the summer, so that any variation of the rating curve could be detected early. At the end of the season the one in use was again rated by the writer, at Calxico, Cal., and it was found that if any change had taken place it was too small to necessitate a change in the table.

The meters could be used on either rod or cable. Eight 1-foot sections of rod, graduated to tenths of a foot, were carried.

When the meter was used on a cable the lower 18 inches of cable was replaced with a section of strong piano wire, with a swivel harness-snap connection to the hanger rod attached to the meter.

Two 6-pound lead torpedo weights were carried, while it was found necessary to use 24 pounds of lead in the New York Canal, with velocities up to 6.6 feet per second in depths of 6.62 feet.

On the work done by the writer and S. T. Harding, wherever the meter was used on a rod the latter rested on a foot piece which in turn rested on the bottom of the channel. For use in wooden flumes a small 4-pronged plug was made to screw up into the rod and project out below the foot piece about 0.01 foot. This was easily forced down into the soft pine or redwood composing the floor and prevented the foot from skidding out beneath the meter under the pressure of water. A guy wire made of piano wire was used in high velocities, whether the meter was held on a cable or on a rod. This guy was equipped with a turnbuckle so that it could be adjusted in length and would hold the meter so that the latter took a position in the vertical plane through the front edge of the gauging bridge.

Meter stations.—As it was desirable to measure the discharge in canals near the reaches to be tested for the value of n , it was necessary to provide some form of footbridge for small canals and a cable station for canals of such widths that a temporary footbridge was impracticable. For small canals a piece of clear Oregon pine, 2 inches by 8 inches, 16 feet long, was found to make the best bridge. It would span a ditch about 14 feet wide without bending appreciably under the weight of one man. In a few cases standard wading methods were used. Where ditches were slightly wider than this and quite shallow a light tower of wire-trussed 2 by 2 pieces carried the end of the plank out over the water while measurements were made in the verticals between the bank and about 3 feet from the tower. The plank was then changed to the other side of the canal and the tower placed in the portion of the canal previously measured, and the meter measurements in the verticals resumed. Thus at no time did the meter approach closer than about 3 feet to the tower, and the legs of the latter were so small that but little water was disturbed by their presence. In order to measure canals up to about 90 feet in surface width a portable meter station was provided as follows:

A rating car was constructed like the body of a fiber steamer trunk. The covering had no hinges, but was held by trunk fasteners and twin locks, one on each side. When the cover was off iron arms carrying 6-inch sheave wheels and hinged to each end of the car were raised to a vertical position. Coiled in the bottom of the car was carried 130 feet of high-grade haulage cable, three-eighth inch in diameter. Steel standards, turnbuckles, pins, and all other accessories also were packed in the car during moves from place to place. This equipment assembled into a meter station, as shown in Plates IX and XII.

Hook gauges.—Two gauges of the Boyden type were used for determining the fluctuation in the surface elevation of the water throughout the experiments. They were not as well adapted for deter-

mining the exact surface of the water at the ends of the reach in order to measure the fall as was the following arrangement.

Bench marks.—In his experiments in Utah, S. Fortier determined the hydraulic slope of the water surface by leveling between the tops of nails, sharpened at both ends and driven into stakes whose tops were below the surface of the water.¹ After considerable experimentation the writer decided that this general arrangement was better than that involving a line of levels between the ends of the reach and in addition another chance of error in measuring down from the

established bench marks to the surface of the water. However, the writer modified Dr. Fortier's plan in the following manner:

It was found that driving the nail, sharpened at the top as well as at the bottom, dulled the point at the top so that it did not make a good point in order to get a "bead" on the surface of the water in a stilling box, and it also did not make a solid bench mark from which to run levels. A better bench mark would be the ordinary top of a well-made wire nail, but this is not directly adaptable, as it can not be driven to a nicety as a surface gauge. To obviate this feature the device shown in figure 1 was constructed. It consists of a motor-cycle spoke soldered into a hole near the edge of the surface exposed by cutting off a three-eighths inch punch. The spoke was bent in the form of a buttonhook and carefully sharpened. The end of the spoke forming the pointed hook was originally threaded for the nipple, which was retained and served as a protection to the point in carrying the device. The final sharp point is in the same plane as the clean

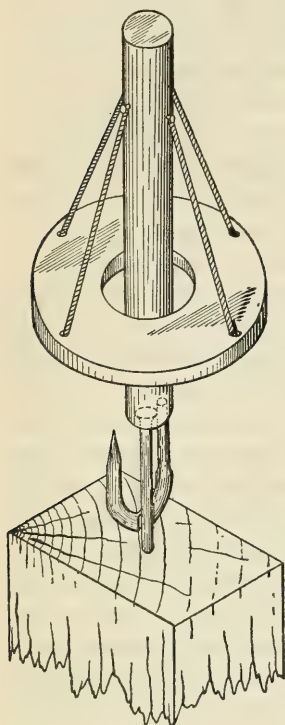


FIG. 1.—Hook device for setting nail head flush with water surface, two-thirds size.

cut end of the punch. Therefore, if the wire nail is driven by means of the punch, in much the same manner as a carpenter sets a nail below the surface of wood with a carpenter's punch, then the top of the wire nail is just flush with the surface of the water when the sharp point of the hook shows at the surface of the water as an ordinary hook gauge. This presupposes that the punch has been held truly vertical in setting the nail. This was assured in the following manner: Near the top of the punch two holes one-sixteenth inch in diameter were bored at right angles to

¹ U. S. Geol. Survey, Water-Supply and Irrig. Paper 43 (1901).

each other. Through these holes a well-oiled fishline formed a four-tie suspension for a perforated disk. The hole in the disk was a trifle larger than the punch which passed through it, so that when held truly vertical the disk acted as a plumb bob, not touching the punch at any point. A very slight leaning of the punch caused the disk to touch, which of course warned the operator that the punch must be plumbed.

In concrete-lined sections and in wooden flumes it was not practicable to use the above device, so a thin headed wire nail was driven horizontally into the side at the water surface. In many cases it was not possible to use a stilling box with such a mark, but it is believed that very little error results where the same operator sets all the marks with the same relation to top and bottom of whatever surface fluctuations exist. Wherever the velocity is sufficient to cause much doubt in the mind of the operator as to the accuracy of the mark, then the total fall between the two ends of the reach tested is so great that any error of a few thousandths is but a very small percentage of the total fall.

Stilling box.—A tin salve box about 3 inches in diameter made a very good stilling box. A hole about three-eighths inch in diameter was made in the center of the bottom. After the nail had been started in the top of the stake in the canal, the box was set over the stake, with the nail projecting through the hole. When the box rested on top of the stake water entered and withdrew slowly and quietly, so that a quiet, definite surface was maintained in the box, and the top of the nail was driven to this surface.

Trimming canal section for measurement.—Where it was necessary to make a current-meter measurement for discharge in a canal and grass or moss was liable to clog the meter and make inaccurate the measurement, or the bottom was slightly uneven, the sides and bottom were neatly trimmed, and all interfering growths removed by means of a sharp short-handled hoe.

FIELD METHODS.

The general method used by the writer in conducting the measurements for the field data was as follows: Minor changes were sometimes necessary for various reasons.

A length or reach of the canal to be tested was chosen. The discharge measurement was started immediately, preferably at the center of the reach chosen. While the measurement was progressing, the length of the reach was carefully chained, the final length being determined by actual position of the two nails driven to the water surface at the ends of the reach. The upstream nail was always set first, so that the party walked downstream with any slight change in volume of the discharge rather than have this change pass them,

as it would if the lower nail were set first. Enough cross sections were taken to determine the mean water area and length of wetted perimeter throughout the reach. Nails were set with their tops flush with the water surface at each end of the reach. Levels were then run between these nails as bench marks. Temperatures of air and water were taken. After all these data had been taken the chief of party was familiar enough with the conditions to write an intelligent description covering the features influencing the flow of water throughout the reach tested.

Throughout the descriptive matter in this publication station 0 is at the upper end of the reach, and integral stations represent 100-foot intervals below station 0.

Canal reach.—Actual conditions encountered in the operation of irrigation systems and under which canals must carry water were those desired, as it was believed the designer must take these into consideration in developing the hydraulic elements of his proposed canal. Other things being equal, a reach of canal 1,000 feet long was chosen with quite uniform flow, not only throughout the reach but also up and down stream so far as conditions might influence results. These reaches were chosen on tangents, on curves, and on both, in order to determine the influence of curves on the retardation factor.

Discharge measurements.—Small discharges were, when practicable, measured with a Cipolletti weir, under standard conditions. Discharges of more than 4 second-feet were measured with the current meter. The surface widths of ditches less than 10 feet in width were divided by vertical lines one-half foot apart. Those of canals more than 10 feet in width were divided into approximately 20 verticals, the sections thus formed near the banks being narrower than those toward the middle, for the reason that the velocity changes more rapidly near the banks. The average velocity in the verticals was determined, as a rule, by the multiple-point method, interpreted through vertical velocity curves. In any one vertical the meter was held at points 0.2, 0.4, 0.6, and 0.8 of the total depth below the surface of the water. In addition to these points, at approximately every other vertical, the meter was held at points 0.1 or 0.2 foot (depending on the surface velocity and consequent roughness) below the surface, and just clearing the bottom. These points gave the necessary information to plot correctly the vertical velocity curves between the surface of the water and the point 0.2 of the depth below the surface and between the bottom of the channel and the point 0.8 of the depth below the surface. In addition to all of these points, in many verticals the meter was held at a point 0.3 of the depth below the surface for the purpose of developing the point representing approximately the maximum velocity in the vertical. The velocity at this

point does not always correctly represent the maximum, since in various verticals taken throughout the summer, in many kinds of channels, the maximum was found at points varying all the way from 0.2 depth to 0.8 depth. These statements refer, of course, to velocities found by holding the meter at these particular fractions of the depths. A close study of any one vertical might show that the maximum velocity occurred at some place between these points, but that phase was immaterial to the studies covered in this publication. The necessary corrections were applied to the velocities indicated near the bottom and surface, on account of the fact that the cup current meter does not run true to standard rating curve when held nearer the surface than 0.3 of a foot and when held near the bottom.¹

The particular points at which to hold the meter were chosen with a view to determining the variations from the discharge of water found in this way that would be found if shorter and more generally used commercial methods of meter gauging had been employed. The various points at which the current meter was to be held were determined as follows: After the tape had been stretched across the canal at the section where the measurement was to be made a bench mark was set at the surface of the water near one bank. The depths at the various verticals were determined by taking with the level the difference in the rod readings between the rod held on the bench mark at the water surface and the rod held at the bottom of the channel. This method is better than using a graduated sounding rod, for the reason that all error due to water climbing the rod is eliminated. This method may be used in high velocities through the main portion of the channel for the reason that a nail can always be set near the bank, where the velocity is much lower than near the center. Where the conditions were such that the meter was to be used on a cable, then the desired points at which to operate it in any vertical were found by multiplying the depth of the vertical by 0.2, 0.4, 0.6, and 0.8 and holding the meter the resulting distances below the surface. Where the meter was to be used on a rod, since the bottom of the rod rested on the bottom of the channel for all measurements and the meter is set on the rod while the rod and meter are out of the water, then the distances below the surface of 0.2, 0.4, 0.6, and 0.8 depth become the distances above the bottom of 0.8, 0.6, 0.4, and 0.2, respectively, of the depth, and are so set on the meter rod.

Having taken the soundings and computed the depths in each vertical at which the meter was to be held, the actual meter runs were made. These were as a rule continued at each point for the nearest number of tens of revolutions in a period of about 30 seconds, the

¹ For a discussion of this phase of current meter use, see U. S. Dept. Agr., Jour. Agr. Research, 2 (1914), No. 2, p. 77.

actual time to the tenth of a second being taken for 20, 30, or 40 revolutions, or whatever the number might be. This method of operating a meter is better than the old one of running the meter for a given number of seconds, thereby introducing an error due to fractional revolutions.

Adjustable hook gauge.—At some point within sight of the man operating the meter a small hook gauge was set. Its range was about 0.6 foot with a vernier reading to thousandths of a foot. This gauge was used to determine the rise or fall of the water surface in the canal during the measurement. The final accepted elevation of the water surface was the mean elevation throughout the meter measurement. All soundings for cross section and the final setting of the bench marks from which the hydraulic grade was determined were based on this mean value of the elevation of the water surface.

Hydraulic grade.—Hydraulic grade was determined during the latter part of or after the measurements for discharge. In earthen channels stakes were firmly driven at each end of the reach chosen until the top of the stake was about 0.07 foot below the surface. After the wire nails were carefully set, as described on page 10, a line of levels was run between the bench marks at the ends of the reach. The level was kept in careful adjustment, and in addition all instrumental errors were obviated by equalizing the sights. This line of levels was as a rule determined by one sight in each direction. A clear-cut target was set very carefully, and the vernier read by both levelman and rodman, independently. Numerous tests showed that the differences obtained in the total fall between the ends of a reach were well within the allowable error for careful leveling.

Data from which to determine the average value of the hydraulic mean depth, comprising sufficient cross sections taken throughout the length of the reach tested, were taken as a rule by means of a tape and level readings on a rod held at the bottom of the channel at sufficient verticals to give true values of the area and the wetted perimeter. It was obviously impossible to drive stakes and set nails vertically in the tops thereof in flumes and concrete-lined sections. In these sections wire nails were driven horizontally into the bank at the water surface, the head of the nail forming a knife edge which quite clearly defined the surface of the water. They may be protected by stilling boxes in low velocities, and in high velocities the fall is so great that refinement in levels is neither practicable nor necessary. In concrete linings the ends of the reach were so chosen that they came at expansion joints, where it was not a difficult matter to drive a nail or, in cases where the lining formed an unbroken surface, a small hole was first drilled with a machinist's centering punch and the wire nail set in this hole.

OFFICE EQUIPMENT AND METHODS.

Multiplication, division, and addition were performed on mechanical devices. Areas included within vertical velocity curves were determined with planimeters and checked by arithmetical ordinates. Vertical velocity curves were drawn through platted points by using xylonite parabolas. The wetted perimeters were determined by stepping around cross sections, plotted to such a scale that the length of the perimeter could be read as closely as the measurement in the field would warrant. Checking was done by means of slide rules and plotted curves showing the values of n for various other hydraulic elements.

CORRECTION FOR VELOCITY HEADS.

In order to bring out the influence of the correction for the difference in velocity heads when there is a difference in areas at the ends of the reach, a concrete example is given:

Test No. 175, made on the Salt River Valley Canal, Arizona. The various items of the data were as follows:

Example showing correction for change in velocity heads.

Length of reach.....	feet..	900.0
Assumed elevation of water surface at station 0.....	do....	90.000
Elevation of water surface at station 9.....	do....	89.319
Fall in water surface.....	do....	00.681
Area at station 0.....	square feet..	38.610
Area at station 3.....	do....	40.41
Area at station 6.....	do....	45.09
Area at station 9.....	do....	43.35
Discharge, found by current meter.....	second-feet..	131.33
Mean area throughout reach, A.....	square feet..	42.16
Mean velocity throughout reach, V.....	feet per second..	3.115
Mean velocity at station 0.....	do....	3.40
Mean velocity at station 9.....	do....	3.03
Velocity head for velocity at station 0.....	foot..	.1797
Velocity head for velocity at station 9.....	do....	.1427
Difference in velocity heads.....	do....	.0370
This difference added to fall, =00.681+0.0370=.....	do....	.718
Slope, s , without correction for velocity heads.....		.00075667
Slope, s , corrected for velocity heads.....		.00079778
Mean wetted perimeter throughout reach.....	feet..	19.52
Mean hydraulic radius throughout reach.....	do....	2.158

Using the above data and solving equation 4, page 4, the value of 0.0217 is found for n if the slope as found by the level, uncorrected for velocity heads, is used. If the corrected slope is used, a value of 0.0223 for n is found. The change due to this correction is academic rather than practical for the lower velocities, but in such as are found in some flumes and concrete sections the change is very material and should not be disregarded.

ELEMENTS OF FIELD TESTS TO DETERMINE RETARDATION FACTORS IN KUTTER AND CHEZY FORMULAS.

In the following pages are arranged a table (Table I) showing the hydraulic elements followed by text matter giving brief descriptions of the general conditions obtaining at the canals measured by the writer and his associates during the season of 1913 with a few tests made in the two preceding years. In both the table and descriptions the experiments are arranged in groups according to the material of the containing channel, while the order within each group follows an ascending value of n , except where several tests were made on the same reach of canal with various discharges of water, in which case tests on that particular reach are not separated.

EXPLANATORY NOTES ON TABLE I.

Column 1 gives the consecutive numbers, which refer to the order followed in the discussions in the following pages and in the appendix.

The small letter a after the number refers to the appendix.

Previously unpublished experiments by members of the force of this office are discussed in the text, while the essential data secured from other sources are abstracted in the appendix.

Column 2 shows the authority and his experiment number where such was carried. The symbols referring to members of this force are as follows:

B refers to Don H. Bark, irrigation engineer in charge of work for this office in Idaho.

F refers to Burton P. Fleming, of the department of mechanical engineering, State University of Iowa.

G refers to W. B. Gregory, irrigation engineer, head of department of experimental engineering, Tulane University, La.

H refers to Sidney T. Harding, at that time irrigation engineer in charge of work for this office in Montana.

McL refers to Walter W. McLaughlin, at that time irrigation engineer in charge of work for this office in Utah.

S refers to the writer, Fred C. Scobey, irrigation engineer at large, in charge of experiments on the flow of water in channels.

The symbols referring to other sources, most of which are publications, are as follows:

RS refers to the United States Reclamation Service, through whose courtesy we were allowed access to the records of experiments conducted by various members of the service.

JBL refers to J. B. Lippincott.¹

VMC refers to V. M. Cone, in charge of the work of this office in Colorado.²

SF refers to Samuel Fortier, Chief of Irrigation Investigations.³

W refers to C. C. Williams, professor of railway engineering, University of Kansas.⁴

Column 3 refers to the classification, showing the relative weight to be given the data, A signifying first-class conditions for experimentation. B and C show second and third class conditions, such as too short a reach, a doubtful method of measuring discharge, proximity of disturbing features in the canal, and so on.

Column 5 shows the general shape of the canal cross section, referred to in figure 2. When considered in connection with columns 6, 7, 8, 9, and 11, an idea of the water section may be secured.

¹ Tests described in Engin. News, 57 (1907), No. 23, p. 612.

² Tests selected from Colorado Sta. Bul. 194 (1914).

³ Tests selected from U. S. Geol. Survey, Water-Supply and Irrig. Paper 43 (1901).

⁴ Tests described in Univ. Colo. Studies, 7 (1910), No. 4, p. 237.

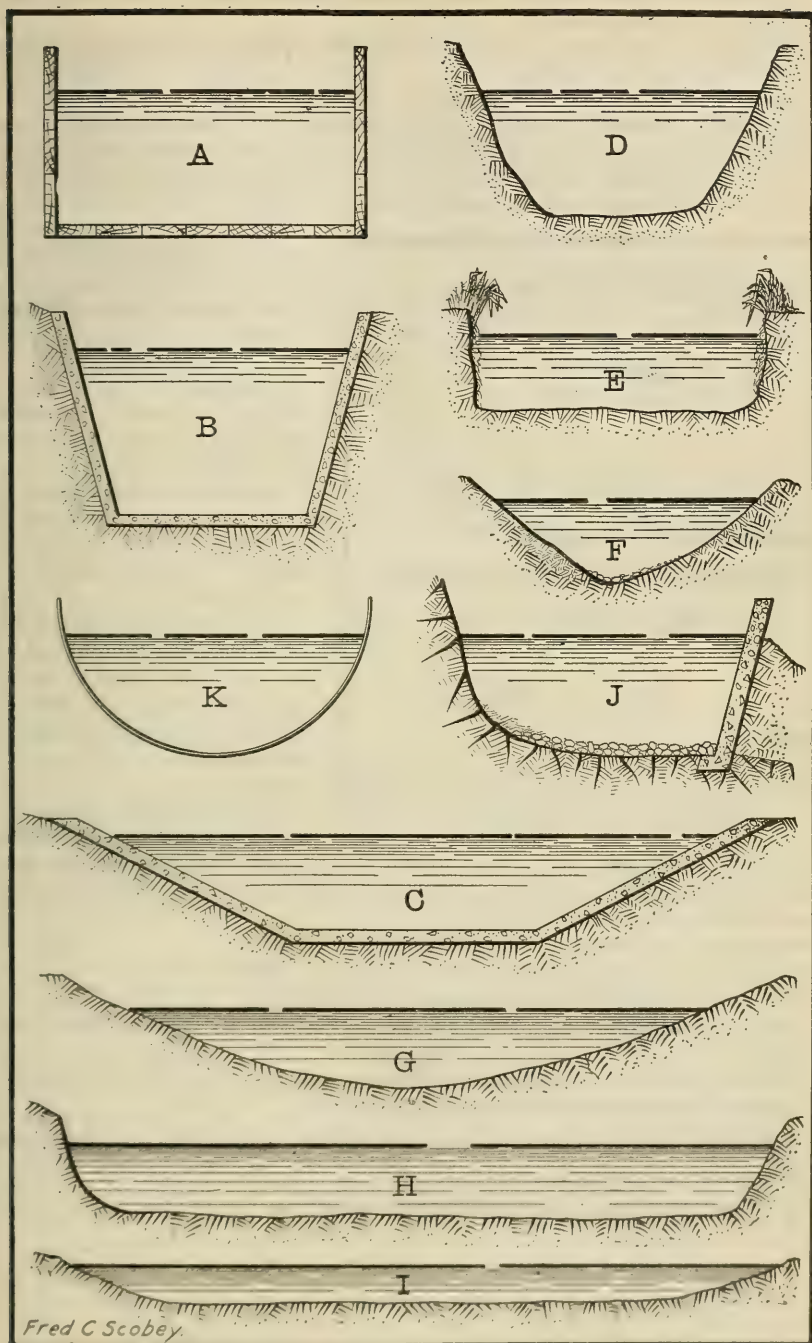


FIG. 2.—Typical shapes of channels used in classifying data in column 5, Table 1.

Column 10 shows the method of securing all depth determinations from which areas and perimeters were secured.

ON refers to office notes. Taken in connection with elevations secured at time of test.

SG refers to a special gauge of some form. Those noted were quite accurate.

LR refers to a difference between level readings on a rod. This obviates all defects of water climbing up the rod, and is the best method, in the opinion of the writer.

S refers to soundings with a graduated stick or rod and although quite accurate in low velocities is uncertain where water climbs up the rod.

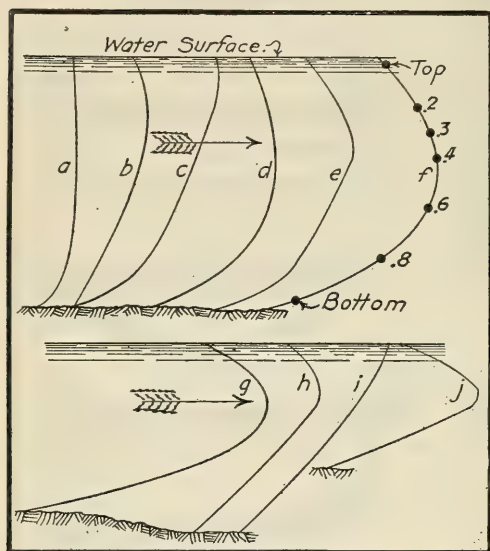


FIG. 3.—Typical vertical velocity curves and depths at which meter was held. See column 15, Table 1.

the surface was accepted as the mean for the vertical. Extensive experiments show that the results of this method as a rule are too high and for this reason tests made in this manner are not given full weight.

RC signifies the discharge was taken from a rating curve.

W refers to a weir measurement, under standard conditions.

C after the W signifies that a trapezoidal or Cipolletti weir was used.

Column 15 shows the typical shape of the vertical velocity curves, referred to in figure 3.

Column 23 shows the various wind conditions: C signifies calm; U signifies upstream; D signifies downstream; and A signifies across.

Where of sufficient importance to seriously affect results, additional information is given in the text.

The other columns are considered self-explanatory.

T refers to measurements by tape on the outside of a flume.

Column 14 shows the method of securing the discharge measurement.

M refers to a current meter.

I signifies the integration method was used. Extensive tests showed that full weight may be accorded this method.

VC signifies that the mean velocity was secured by means of the multiple-point method interpreted through vertical velocity curves.

—2+8 signifies the mean of the velocities obtained at 0.2 and 0.8 depths in each vertical was accepted as the mean of the vertical. Extensive experiments showed this method may be given full weight.

—6 signifies the velocity obtained at 0.6 of the depth below

TABLE I.—Elements of experiments for the determination of retardation factors in Kutter and Chezy formulas.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Coefficients of retardation.			23		
Reference number.	Experiment.	Class.	Name and description of channel.	Shape of channel.	Length of reach tested.	Approximate surface width.	Approximate maximum depth.	Average depth.	Depth determination.	Area of water section.	Mean velocity per second.	Discharge per second.	Discharge determination.	Velocity curve.	Wetted perimeter.	Hydraulic mean radius.	Hydraulic grade per foot.	n Kutter.	C Chezy.	Air (shade).	Water.	Wind condition.	
					Feet.	Feet.	Feet.	Feet.		Sq. ft.	Feet.	Cu. ft.	M-VC.	a.	Feet.	Feet.	Feet.		19	20	21	22	
1	236	C	New York Canal.....	C	602.0	59.0	6.6	5.6	ON	332.9	5.48	1,824.00	M-VC		63.00	5.230	.0001611	0.0101	188.7	72	62	C.	
2	237	C	Main canal, Boise project.....	C	2,400.0	49.1	2.97			123.5	3.81	469.37	M		50.30	2.45	.0003333	.0130	133.4				
3	238	C	do do, Boise project.....	C	1,900.0	53.7	4.75			219.5	4.68	1,027.37	M		56.5	3.88	.0003875	.0113	140.6				
4	239	C	Sulphur Creek wasteway.....	K	1,300.0	2.3				11.75	20.62	242.00	M		9.03	1.36	.0144	.0108	150.5				
5	240	C	Sulphur Creek wasteway, curve.....	K	900.0	2.4				12.67	19.13	242.00	M		9.32	1.36	.0206	.0140	114.1				
6	241	C	Los Angeles conduit, curve.....	C	700.0					5.16	2.81	14.51	M-2+8.		6.22	.83	.00051	.0108	136.7				
7	242	C	do do.....	C	700.0					5.00	2.71	13.55	M-2+8.		6.12	.82	.00051	.0111	132.6				
8	243	C	Tunnel 23, San Gabriel plant.....	A	318.0	4.5	3.5		SG	15.73	4.74	74.64	M-2+8.		11.50	1.37	.00082	.0113	141.6				
9	244	C	Dry Creek flume, troweled cement.....	A	514.5	7.9	1.30		LR	9.76	15.78	154.00	M		10.35	.94	.01459	.0115	134.5				
10	245	C	Tunnel 15, San Gabriel plant.....	A	446.0	4.5	3.13		SG	14.08	5.01	70.60	M-2+8.		10.70	1.31	.00126	.0128	123.3				
11	246	C	Ridenbaugh, very smooth.....	C	1,699.0	22.8	4.30	3.10	LR	70.73	4.15	293.62	M-VC		25.20	2.81	.0002371	.0110	161.5				C.
12	247	C	Ridenbaugh, tangent.....	C	901.0	22.0	3.80	2.76	LR	60.60	3.65	221.20	M-VC		23.90	2.54	.0002508	.0121	144.8				C.
13	248	C	Ridenbaugh, tangent and curves.....	C	1,819.0	22.0	3.80	2.76	LR	60.50	3.65	221.20	M-VC	d.	23.90	2.54	.0002337	.0129	136.1				C.
14	F-3	C	do do.....	C	1,020.6	23.6	4.55	3.24	SG	76.59	4.14	316.70	M-VC		26.34	2.91	.000283	.0124					
15	150	C	Ridenbaugh, curves.....	C	2,400.0	15.5	1.65	1.36	LR	20.59	2.45	50.49	M		15.9	1.30	.000329	.0132	118.1				
16	151	C	Lizard chute No. 1, smooth.....	A	180.0	3.1	.86		LR		15.05	16.42	M			.29	.08244	.0124	97.4				
17	152	C	do do.....	A	180.0	3.0	1.1		LR		6.18	2.04	M			.10	.08244	.0130	67.2				
18	153	C	Long Pond chute, smooth.....	A	600.0	4.4	1.53		ON	6.24	19.70	122.94	M		7.24	.86	.02971	.0123	122.4				
19	154	C	Long Pond chute, same reach.....	A	600.0	4.4	.71		ON	2.78	12.87	35.79	M		5.68	.49	.02978	.0125	106.6				
20	155	C	Umatilla project, smooth.....	C	932.0					2.76	2.06	5.70	M		4.76	.58	.0007	.013	102.0				
21	156	C	Umatilla project, tangent.....	K	640.0		4.00			28.95	7.10	205.00	M		13.50	2.12	.01014	.0132	129.0				
22	157	C	Umatilla project, wavy.....	K	1,075.0		2.98			28.71	7.15	205.00	M		13.50	2.12	.01014	.0132	129.0				
23	158	C	Umatilla project, curve.....	K	220.0		4.05			29.40	6.94	205.00	M		13.50	2.15	.00273	.0189	90.0				
24	230	B	Arena chute, smooth, straight.....	C	1,900.0	6.1	.24		ON	321.10	8.21	337.00	M-VC		59.20	5.43	.0006389	.0138	139.4	73	63	A.	
25	231	B	North Side Twin Falls, Main ditch.....	C	1,900.0								M-VC		22.05			.0139	77.2				
26	F-1	B	Davis and Weber, medium smooth.....	C	552.0	27.8	2.89	2.49	SG	69.29	3.82	634.50	M-VC		29.66	2.34	.000413	.014	125.7				
27	M-1	B	do do.....	C	34.20			1.75			3.89	133.30	M-I		23.95	1.50	.000626	.0144	110.0				

TABLE I.—Elements of experiments for the determination of retardation factors in Kutter and Chezy formulas—Continued.

1 Reference number.	2 Experiment.	3 Class.	4 Name and description of channel.	5 Shape of channel.	6 Length of reach tested.	7 Approximate surface width.	8 Approximate main depth.	9 Average depth.	10 Depth determination.	11 Area of water section.	12 Mean velocity per second.	13 Discharge per second.	14 Discharge determination.	15 Velocity curve.	16 Wetted perimeter.	17 Hydraulic mean radius.	18 Hydraulic grade per foot.	Coefficients of retardation.			23 Temp-erature.	
																		19 Kutter.	20 Chezy.	21 22 Air (shade). Water.		
28	F-2.		Concrete lined—Continued. Davis & Weber, medium smooth.	C...	Feet. 468.5	Feet. 22.8	Feet. 1.77	Feet. 1.59	SG...	Sq. ft. 36.18	Feet. 3.34	Cu. ft. 120.90	M-VC...	Feet. 24.07	Feet. 24.07	Feet. 1.50	Feet. 0.00619	0.0146	109.0			
29	S-13.	A	do.	C...	1,000.0	23.0	2.60	2.34	LR...	53.80	3.94	212.00	M-VC...	f.	26.00	2.07	.000629	.0154	109.7	85	64	A.
30	B-10.	A	King Hill rough, curves.	C...	925.0	16.5	2.00	1.62	LR...	21.40	2.55	54.64	M-2+8.		17.16	1.25	.0004497	.0143	107.5			C.
31	H-29.	A	Hamilton mill flume, new.	C...	3,000.0	7.0	4.11	4.11	LR...	27.90	3.86	107.60	M-VC...		14.38	1.94	.00062	.0149	111.4			
32a	VMC	A	South Canal.	B...	730.0	14.7	1.77	1.71	LR...	23.66	4.71	111.30	M...		16.82	1.41	.00151	.0155	102.1			
33a	VMC	A	do.	B...	210.0	10.4	5.77	5.68	LR...	5.78	15.52	89.80	M...		11.28	.51	.07180	.0158	80.8			
34a	VMC	A	do.	B...	142.0	13.3	.45	.40	LR...	5.28	11.32	59.80	M...		13.92	.38	.07230	.0171	68.4			
35a	S-49.	A	Sanderfer, smooth, tangent.	B...	743.3	3.5	1.80	1.43	LR...	5.00	3.74	18.71	M-VC...	h.	5.94	.84	.002375	.0155	92.0	92	70	C.
36a	JBL-8.	A	Santa Ana sand.	B...	1,000.0					10.21	2.62	26.79	M-2+8.		5.90	.82	.00106	.0157	89.2			
37	S-37a.	A	do.	C...	755.8	5.4	.78	.57	LR...	3.06	1.86	5.71	M-VC...		5.67	.54	.00099	.0160	80.2	96	81	C.
38	S-37.	A	do.	C...	755.8	5.4	.80	.62	LR...	3.33	1.71	5.71	M-VC...	e	5.74	.58	.001184	.0192	65.2	96	81	C.
39a	JBL-7.	A	Cotton, tangent, moss.	B...	1,000.0	2.6	.90	.80	S...	6.75	2.27	15.34	M-2+8.		6.88	.98	.0007	.0167	87.7			
40	S-11.	A	South Cottonwood Ward, sand	B...	350.0	21.0	1.58	1.52	LR...	2.07	1.38	2.86	M-1		3.98	.52	.000694	.0171	72.6	79	51	C.
41	S-55.	A	Modesito main, rocks.	B...	755.6	21.0	1.58	1.41	LR...	32.02	3.58	114.80	M-VC...	e	23.22	1.31	.001157	.0174	89.7	106	75	C.
42	S-63.	A	Santa Ana main, deposit, sand.	B...	1,082.8	11.5	1.38	1.41	LR...	16.18	1.67	27.06	M-VC...	e	13.25	1.22	.0032208	.0176	84.6	83	76	C.
43	S-70.	A	Los Nietos, deposit, sand.	B...	1,000.0	4.4	1.12	1.52	S...	6.49	2.89	19.36	M-VC...	e	6.81	.98	.001444	.0188	76.8	86	76	C.
44	S-67.	A	Arroyo Ditch, tangent, moss.	B...	1,000.0	4.1	1.78	1.60	LR...	6.56	2.83	18.34	M-VC...	f.	6.89	.95	.001449	.0188	76.2	80	82	C.
45	S-31a.	A	North Canal, rough, tangent.	B...	1,013.0	12.9	2.78	2.58	S...	33.38	3.94	98.30	M-VC...	e	17.20	1.94	.000525	.0177	92.5	86	62	D.
46	S-31b.	A	North Canal, tangent and curve	B...	1,013.0	12.9	2.78	2.58	S...	32.52	3.92	98.30	M-VC...	e	17.10	1.90	.000639	.0187	86.9	86	62	D.
47	S-30a.	A	North Canal, tangent.	B...	1,013.0	12.7	2.22	2.03	S...	26.26	2.85	74.86	M-VC...	f.	16.15	1.63	.000759	.0176	90.8	78	72	C.
48	S-30b.	A	North Canal, tangent and curve	B...	1,013.0	12.4	1.10	1.09	S...	26.65	2.87	74.86	M-VC...	f.	16.10	1.62	.000759	.0176	90.8	78	72	C.
49	S-32a.	A	North Canal, tangent.	B...	1,013.0	12.7	2.22	2.03	S...	26.26	2.85	74.86	M-VC...	f.	16.15	1.63	.000759	.0176	90.8	78	72	C.
50	S-32b.	A	North Canal, tangent and curve	B...	1,013.0	12.4	1.10	1.09	S...	26.65	2.87	74.86	M-VC...	f.	16.10	1.62	.000759	.0176	90.8	78	72	C.
51	S-38.	A	Main, Orland project.	C...	301.0	21.0	2.20	1.77	LR...	12.61	2.04	23.74	M-VC...	h.	13.87	.91	.001021	.0206	67.1	71	80	C.
52a	JBL-4.	A	Upper, Riverside, two curves.	C...	600.0					37.09	2.27	84.32	M-VC...	e	22.75	1.63	.000574	.0211	74.3	98	82	C.
53	S-68.	B	Small ditch, cement wash.	C...	575.4	2.7	1.70	1.04	S...	6.96	1.22	8.90	M-2+8.		4.52	.62	.000539	.0220	56.1	80	70	C.
54	S-75.	A	Lower, Riverside, rough broken.	B...	699.0	11.0	1.30	1.14	LR...	12.57	1.88	23.64	M-VC...		12.30	1.02	.000851	.0221	63.8	78	73	C.
55	S-71.	A	Upper, Riverside, sandy bot- tom.	B...	329.6	12.9	2.20	2.07	LR...	26.68	1.79	47.83	M-1...		16.64	1.60	.000482	.0231	64.4	96	71	C.
56a	JBL-3.	B	Upper, Riverside, sand, grass.	B...	800.0					30.92	1.96	60.52	M-2+8.		20.74	1.49	.00092	.0284	52.9			

[illegible]

TABLE I.—Elements of experiments for the determination of retardation factors in Kutler and Chezy formulas—Continued.

1	Reference number.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Coefficients of retardation.				23
																			19	20	21	22		Temp- era- ture.
				Name and description of channel.	Shape of channel.	Length of reach tested.	Approximate surface width.	Approximate maxi- mum depth.	Average depth.	Depth determination.	Area of water sec- tion.	A Mean velocity per second.	Q, Discharge per sec- ond.	Discharge determina- tion.	Velocity curve.	P Wetted perimeter.	R Hydraulic radius, mean.	S Hydraulic grade per foot.	n Kutter.	C Chezy.	Air (shade).	Water.	Wind condition.
<i>Metal flumes.</i>																							
98a	VMC...	B...		Minnesota, smooth, tangent...	K...	200.0	2.8	.66		S...	1.17	6.01	7.04							0.0099	136.2		
99a	VMC...	B...		Garland, smooth, tangent...	K...	650.0	5.7	1.11		S...	3.66	5.34	19.59	M...						0.01	142.3		
100a	RS...	B...		Boise project, smooth...	K...		2.1	.68				1.66	1.71							0.06	119.7		
101a	RS...	B...		Boise project, smooth, No. 80...	K...		3.1	.75				2.37	3.36							0.17	109.9		
102a	RS...	B...		Mora Canal, smooth, No. 108...	K...		3.5	.70				2.55	4.02							0.11	116.6		
103a	RS...	B...		Yarnell lateral, smooth, No. 172...	K...		2.6	.55				2.88	2.57							0.12	121.5		
104a	VMC...	B...		Garland, smooth, tangent...	K...	325.0	5.8	1.12		S...	4.25	4.40	19.59	M...						0.22	112.5		
105a	RS...	B...		Partridge lateral, projecting bands.	K...		2.0	.57				1.82	1.39							0.12	93.6		
106a	RS...	B...		Golden Gulch, projecting bands.	K...		4.5	1.50				1.43	6.81							0.12	109.9		
107a	RS...	B...		Ten-Mile feeder, projecting bands.	K...		5.2	1.65				1.38	8.08							0.13	109.6		
108a	RS...	B...		South Ridge, projecting bands.	K...		2.2	.50				1.68	1.34							0.13	83.4		
109a	VMC...	B...		King lateral, projecting bands.	K...	300.5	5.1	2.00		ON...	7.32	5.35	39.19	M...						0.17	83.1		
110a	VMC...	B...		do.	K...	189.0	5.0	1.68		S...	5.77	5.10	33.30	M...						0.92	0.0537		
111a	VMC...	B...		do.	K...	635.0	4.2	1.57		ON...	4.65	5.10	23.72	M...						0.17	82.3		
112a	VMC...	B...		Stewart, curve, corrugated iron.	K...	1,745.0	6.0	1.77			7.67	1.92	14.70	M...						0.16	86.6		
<i>Masonry lined.</i>																							
113	S-29...	A...		Jacobs, rubble sides...	E...	225.0	4.2	1.50		S...	5.90	3.82	19.44	M-VC...						0.130	111.5	88	C.
114a	RS...	A...		Cottonwood flume, rubble...	E...		5.7	1.3				6.17	29.42							0.163	89.3		
115	S-27...	A...		Jacobs, unchinked sides...	E...	280.0	7.4	1.95		S...	13.06	1.49	19.44	M-VC...						0.235	61.9	88	C.
116	S-28...	A...		Jacobs, plastered sides...	E...	280.5	5.1	1.77		S...	8.62	2.26	19.44	M-VC...						0.250	55.5	88	C.
117	S-45...	B...		Orr, mortar laid...	E...	213.6	11.5	2.70		LR...	26.02	1.76	45.80	M-VC...						0.298	52.4	70	C.

Earth channels.		Earth channels.															
1188	W-14	Interstate, cemented clay.	G	1,000.0	51.0	3.70	2.53	207.50	4.75	830.00	M-V-C	52.10	3.88	.00017	.012	185.0	C.
119	2	Farmers, cemented clay.	G	1,200.0	51.0	3.90	2.74	139.81	2.56	330.00	M-V-C	53.80	2.40	.000154	.030	133.0	A.
120	1	do.	G	1,200.0	51.0	3.90	2.74	139.81	2.56	330.00	M-V-C	53.80	2.40	.000154	.030	133.0	A.
121	2	Bear River, sediment.	G	1,200.0	51.0	3.90	2.74	139.81	2.56	330.00	M-V-C	53.80	2.40	.000154	.030	133.0	A.
121a	2F-21	Bear River City, sediment.	G	1,200.0	51.0	3.90	2.74	139.81	2.56	330.00	M-V-C	53.80	2.40	.000154	.030	133.0	A.
122	2F-12	Bear River City, sediment.	G	1,200.0	51.0	3.90	2.74	139.81	2.56	330.00	M-V-C	53.80	2.40	.000154	.030	133.0	A.
123	2F-15	Bear River, Corinne Branch, silt.	G	100.0	23.9	2.80	1.94	10.24	3.62	225.55	M	11.85	.86	.00031	.035	102.2	A.
123a	2F-15	Bear River, Corinne Branch, silt.	G	100.0	23.9	2.80	1.94	10.24	3.62	225.55	M	11.85	.86	.00031	.035	102.2	A.
124	SF-22	Bear River, Corinne Branch, loam.	G	18.9	2.24	1.67		31.06	2.02	64.02	M	19.78	1.00	.000273	.0164	96.8	A.
124a	SF-22	Bear River, Corinne Branch, loam.	G	18.9	2.24	1.67		31.06	2.02	64.02	M	19.78	1.00	.000273	.0164	96.8	A.
125a	VMC	Fort Lyons, silt, very smooth.	I	2,600.0	68.0	1.20	1.13	75.60	1.86	140.55	M	66.80	1.13	.00038	.0165	89.5	A.
126	2S-3	Maricopa, hard bed.	H	900.0	29.0	3.00	2.31	66.93	1.28	85.51	M-V-C	13.90	2.20	.0000804	.0166	99.3	A.
127	2S-3	Winter Creek, compact clay.	H	800.0	43.5	1.70	1.02	13.71	.93	12.77	M-V-C	13.90	.99	.0001341	.0170	80.9	D.
128	W-1b	Empire make, sand, gravel.	H	400.0	48.0	4.00	2.83	135.90	2.94	372.10	M-6	41.40	2.84	.00025	.0170	103.0	A.
128a	W-1	Empire make, firm gravel.	H	400.0	48.0	4.00	2.83	135.90	2.94	372.10	M-6	41.40	2.84	.00025	.0170	103.0	A.
130	H-7	Billings Land & Irrigation Co., slick loam.	G	1,000.0	24.0	3.80	2.85	71.20	2.46	175.50	M-V-C	26.30	2.60	.000230	.0174	100.0	A.
131a	VMC	Jarboan Power, clay loam.	H	900.0	13.6	1.40	1.21	16.43	1.96	32.27	M	14.75	1.11	.00049	.0176	83.8	A.
132	H-3b	Cove, sandy loam, grass.	G	600.0	4.5	.75	.53	2.78	.97	2.70	M-V-C	5.00	.47	.000617	.0180	66.6	A.
133	H-3b	do.	G	600.0	4.5	.75	.53	2.78	.97	2.70	M-V-C	5.00	.47	.000617	.0180	66.6	A.
134	H-19	Billings Land & Irrigation Co., silted.	H	1,000.0	20.0	2.90	2.32	46.48	2.30	106.93	M-V-C	21.90	2.12	.000295	.0181	92.0	A.
135	S-82	Grand Canal, hard bed.	H	1,000.0	29.0	2.80	1.99	59.57	2.72	161.75	M-V-C	29.20	2.04	.000438	.0183	90.8	A.
135a	SF-3	Logan, Hyde Park and Smith field.	H	13.7	1.60	1.29		17.80	2.58	45.90	M	14.80	1.20	.00083	.0184	81.5	D.
137	H-18d	Billings Land & Irrigation Co., clay, sandy.	H	750.0	25.5	3.00	2.47	63.10	1.46	92.08	M-V-C	26.90	2.34	.00011	.0186	90.5	C.
138	H-18b	Billings Land & Irrigation Co., same reach.	H	750.0	26.5	3.70	2.99	79.20	1.88	148.66	M-V-C	28.40	2.79	.000152	.0193	91.1	C.
139	H-18a	do.	H	750.0	27												

TABLE I.—Elements of experiments for the determination of retardation factors in Kutter and Chezy formulas—Continued.

Reference number.	Experimenter.	Class.	4	Name and description of channel.	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Coefficients of retardation.			23
																			19	20	21		22
Earth channels—Continued.																						
156a	SF-6	B		Logan and Richmond, clay...	F	Feet.	Feet.	Feet.	Feet.		Sq. ft.	Feet.	Cu. ft.			Feet.	Feet.	Hydraulic grade per foot.	s	c	Chzy.	Wind condition.
157	H-35	A		Bitter Root Valley Irrigation Co.	G	1,000.0	14.9	2.42	2.15	S	32.02	2.14	68.56	M	M-VC	d	17.80	1.740	0.00046	n		Water.
158	H-14	A		Billings Land & Irrigation Co., lateral 2.	G	400.0	8.4	1.40	.98	S	8.20	.78	6.37	M-VC			9.20	.88	0.00175			
159a	SF-4	B		Logan, Hyde Park and Smithfield.	G	60.0	12.0	2.08	1.72		20.61	2.49	51.36	M			13.56	1.52	0.00077			
160	G-1			Morris, bed ploughed, grassy...	I	1,000.0	70.0	4.10	2.98	S	208.50	.43	89.23	M-VC			71.90	2.90	0.000107			
161	H-25	A		Hedge, fine granite, few rocks	H	200.0	16.5	2.65	1.94	S	32.00	2.09	67.00	M-VC			17.80	1.80	0.00044			
162	S-78	A		Birch, Imperial Water Co. No. 1, hard bed.	H	1,000.0	10.0	1.60	1.30	LK	13.05	1.34	17.45	M-VC	e		11.71	1.11	0.003795			
163a	SF-11	I		Point Lookout, sedimented...	I	35.8	3.5	2.25	1.65	S	58.94	1.48	87.29	M			36.73	1.60	0.00027			
164	G-6	G		Crowley, bed harrowed, grassy	G	1,000.0	27.0	5.10	3.08	S	83.05	1.52	68.29	M-VC			27.80	2.99	0.000345			
165a	VMC	G		Bessemer (b), smooth adobe	G	1,600.0	18.2	2.90	2.05	LK	37.27	1.55	57.98	M			19.87	1.88	0.00024			
166a	VMC	G		Bessemer (a), smooth adobe.	G	1,495.0	16.1	3.50	2.31	LK	37.15	1.56	57.98	M			18.15	2.04	0.00036			
167	H-8	A		Big Ditch high line, silted.	H	1,000.0	10.5	1.70	1.17	S	12.32	1.24	15.22	M-VC	e		11.65	1.06	0.00357			
168a	W-2	H		Linden, clean sand.	H	1,000.0	25.0	2.00	1.49	LK	27.30	1.66	42.60	M-6			24.50	1.52	0.00038			
169a	VMC	H		Mesa lateral (b), fine silt bed.	H	600.0	14.7	2.40	2.00	LK	27.40	1.47	40.32	M			76.46	1.66	0.00026			
170a	VMC	H		Rio Grande lateral (c), gravel.	I	1,283.0	25.5	1.90	1.46	LK	33.22	1.39	43.60	M			26.20	1.42	0.00220			
171a	VMC	I		Rio Grande lateral 1, gravel.	I	5,280.0	16.5	1.90	1.46	LK	19.32	1.39	27.16	M-VC			32.80	.60	0.00362			
172	S-64	A		Santa Ana main, cemented sand.	H	1,000.0	16.5	1.30	1.15	LK	18.92	1.44	27.16	M-VC			17.18	1.06	0.00481			
173	S-80	A		California Development Co., central main.	H	998.0	33.0	5.00	4.26	S	161.65	2.08	336.91	M-VC	c		43.80	3.69	0.001682			
174	H-20	A		Billings Land & Irrigation Co., gravel.	H	1,500.0	21.5	2.90	2.36	S	50.90	2.00	102.22	M-VC	e		23.90	2.13	0.00335			
175	S-84	A		Salt River Valley	H	900.0	17.0	3.40	2.48	LK	42.16	3.12	131.33	M-VC	e		19.55	2.16	0.00798			
176a	SF-19	H		Lewiston, clay, moss patches.	H	1,000.0	16.6	2.12	1.66	LK	27.53	1.19	32.72	M			18.08	1.52	0.00020			
177a	W-5	B		Geo. Rist, gravel.	H	1,770.0	12.0	1.30	.92	LK	11.00	1.15	12.70	M-6			12.10	.91	0.00040			
178	H-2	A		Big Ditch, sand bed, mud sides.	G	1,000.0	15.5	3.70	2.43	S	40.10	2.09	83.68	M-VC	f		18.80	2.13	0.00377			

179	H-38...	B...	Ritter Root Valley Irrigation Co.	G...	400.0	37.0	2.75	2.10	S.....	56.80	1.63	92.80	M-VC...	...	28.85	1.57	.000572	.0226	71.8	62	U.
180	S-40...	A...	lateral 10, Orland project	G...	588.0	12.0	1.75	1.24	L.R...	14.82	1.78	26.35	M-VC...	h	13.20	1.11	.0007385	.0228	62.2	95	A.
181	SF-31...	A...	Providence tupper, packed	H...	...	6.5	.63	.51	...	3.29	...	7.31	W...	...	6.80	.48	.00043	.0230	49.3	...	...
182	SF-14...	A...	Bear River lateral, silt and moss.	G...	...	5.5	.95	.71	...	3.89	1.19	4.63	M...	...	6.00	.65	.00075	.0236	54.0	...	...
183	SF-39...	B...	Bear River, lateral 2, silt, grass.	I...	80.0	7.8	.95	.74	...	5.74	1.38	7.90	W...	...	8.12	.71	.000875	.0230	55.4	...	C.
184	SF-39...	A...	Orland South Main...	H...	596.1	21.1	2.50	2.12	L.R...	44.40	1.90	84.32	M-VC...	...	23.00	1.93	.000859	.0231	69.7	95	82
185	SF-9...	A...	Walker tract, loam.	G...	...	19.5	2.70	1.96	...	13.32	1.01	38.55	M...	...	20.90	1.83	.00012	.0232	67.8	...	C.
186	SF-36...	A...	River Branch Canal, few cobbles.	H...	533.0	16.5	2.40	1.80	S...	29.73	2.82	83.86	M-VC...	e	17.98	1.65	.001105	.0235	66.0	90	80
187	SF-1...	H...	Providence, medium gravel	H...	...	6.4	.90	.82	...	5.26	1.90	9.98	M...	...	7.40	.71	.00175	.0238	53.8	...	...
188	SF-5...	C...	College and City, gravel, roots	E...	50.0	3.7	.76	.70	...	2.59	2.53	7.60	M...	...	4.73	.55	.00616	.0238	50.4	...	...
189	SF-27...	B...	Logan, Hyde Park and Thatcher.	G...	100.0	17.6	2.22	1.74	...	30.60	1.97	60.23	M...	...	18.90	1.62	.0006	.0246	63.2	...	...
190	G-4...	B...	Small ditch, new	F...	350.0	3.5	1.10	.69	S...	2.40	.34	.81	M-6...	...	4.15	.58	.0001044	.0246	44.0	69	76
191	SF-18...	B...	College and City, uneven	E...	...	4.4	.88	.80	...	3.51	1.61	5.66	M...	...	5.44	.65	.0016	.0247	50.2	...	...
192	SF-88...	A...	Boulder and White Rock	H...	300.0	7.2	.50	.45	L.R...	90.25	1.82	3.20	M-VC...	h	31.54	.43	.001246	.0248	43.3	55	55
193	H-3...	A...	Billings Land & Irrigation Co., gravel.	H...	1,000.0	28.0	3.90	3.23	S...	30.21	1.82	164.45	M-VC...	...	7.16	2.89	.000248	.0258	68.2	...	D.
194	S-23...	A...	South Side Twin Falls, lateral.	D...	754.0	10.0	2.00	1.49	S...	14.88	1.75	26.06	M-VC...	e	11.50	1.29	.000737	.0259	56.7	...	A.
195	H-1...	A...	Billings Land & Irrigation Co.	H...	1,000.0	27.0	4.25	3.45	...	93.00	2.35	218.33	M-VC...	d	30.80	3.02	.00038	.0259	69.0	90	64
196	SF-63...	A...	Hyrum, rocky, earth bed.	H...	...	5.0	.44	.37	...	1.87	.84	1.57	W...	...	5.28	.35	.0013	.0260	38.9	...	C.
197	H-36...	A...	Bitter Root Valley Irrigation Co.	G...	1,000.0	27.0	2.80	2.19	S...	59.10	1.61	95.30	M-VC...	...	29.00	2.04	.00032	.0260	63.0	...	...
198	S-14...	A...	North Ogden, gravel.	F...	800.0	8.5	1.75	1.38	S...	11.71	1.72	20.12	M-VC...	e	9.77	1.20	.000831	.0262	54.5	66	58
199	SF-56...	A...	Main Branch Turlock district, hardpan.	I...	1,000.0	29.0	1.75	1.26	L.R...	35.24	.99	35.01	M-VC...	h	27.80	1.27	.000263	.0262	54.4	93	84
200	H-4...	A...	Billings Land & Irrigation Co., gravel.	H...	1,000.0	24.0	3.50	2.67	S...	64.10	2.67	171.34	M-VC...	d	26.95	2.38	.00072	.0264	64.2	71	62
201	VMC...	A...	Rocky Ford(a), loose sand bed	H...	1,000.0	14.5	2.00	1.69	L.R...	24.44	1.68	41.20	M...	...	16.08	1.52	.00058	.0266	56.5	...	...
202	S-60...	A...	Salt Lake City and Jordan	E...	600.0	9.5	2.25	2.19	S...	20.28	1.57	31.86	M-VC...	e	13.21	1.57	.0004783	.0267	57.3	...	A.
203	W-1...	B...	Loveland and Greeley	I...	...	4.0	2.30	1.74	...	93.20	1.69	106.09	M-6...	...	35.00	1.69	.00050	.0267	58.2	...	62
204	S-60...	A...	Fullerton, loose sand bed.	G...	600.0	12.0	1.30	1.15	L.R...	13.79	1.14	18.72	M-VC...	...	13.38	1.03	.000493	.0269	50.5	91	76
205	S-90...	A...	Farmers', few rocks	I...	600.0	11.0	.80	.61	S...	6.76	1.41	9.52	M-VC...	h	11.38	.59	.001758	.0270	43.5	82	59
206	H-123...	A...	Billings Land & Irrigation Co., sand bed.	G...	400.0	8.5	1.80	1.16	S...	9.86	1.45	14.28	M-VC...	b	9.68	1.02	.000812	.0271	50.6	...	...
207	H-120...	A...	Billings Land & Irrigation Co., same reach.	G...	400.0	7.5	1.40	.99	S...	7.46	1.23	9.20	RC...	...	8.98	.83	.000842	.0277	46.5	...	...
208	H-126...	B...	do.	G...	400.0	7.0	1.10	.87	S...	6.12	1.04	6.37	M-VC...	d	8.20	.75	.00082	.0294	42.1	...	...
209	S-60...	A...	Yosemite Power Co.	H...	662.6	3.5	.75	.56	L.R...	1.95	1.32	4.14	M...	...	4.14	.47	.003579	.0274	31.6	64	60
210	S-5...	A...	Farley's Ditch lateral, sand bed.	F...	600.0	5.0	1.20	.74	S...	3.70	1.20	2.57	M-2+8...	...	5.63	.66	.001163	.0278	43.2	75	54
211	VMC...	A...	Bessemer (b), fine silt, rocks.	F...	2,002.0	16.4	3.10	2.04	L.R...	33.56	1.26	42.35	M...	...	18.55	1.81	.00028	.0280	55.9	...	...
212	S-20...	C...	South Side Twin Falls, lateral.	D...	718.0	6.5	1.90	1.25	L.R...	8.12	2.50	20.32	M-VC...	e	8.05	1.01	.002683	.0283	48.1	...	C.
213	S-85...	B...	Arizona Canal lateral.	D...	700.0	5.5	1.70	1.10	L.R...	6.09	2.36	14.35	M-L...	...	6.66	.91	.003088	.0284	46.0	100	79
214	VMC...	A...	Rio Grande lateral No. 1, gravel.	I...	5,280.0	43.7	2.40	1.87	L.R...	81.62	4.66	380.00	M...	...	23.70	1.87	.00336	.0284	56.3	...	...
215	S-79...	A...	Beech Imperial Water Co., No. 1, sand bed.	H...	1,000.0	8.0	.90	.75	S...	5.97	.87	5.18	M-2+8...	...	8.67	.69	.000594	.0290	42.8	80	89
216	S-49...	A...	Wheeler, hard bed, looserocks.	F...	1,164.5	10.5	2.00	1.56	S...	16.40	1.18	19.35	M-VC...	...	12.05	1.36	.000411	.0292	49.8	78	66

TABLE I.—Elements of experiments for the determination of retardation factors in Kutter and Chezy formulas—Continued.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Coefficients of retardation.				23
																		19	20	21	22	
Reference number.	Experimenter.	Class.	Name and description of channel.	Shape of channel.	Length of reach tested.	Approximate surface width.	Approximate maximum depth.	Average depth.	Depth determination.	Area of water section.	Mean velocity per second.	Discharge per second.	Discharge determination.	Velocity curve.	d Wetted perimeter.	R Hydraulic mean radius.	s Hydraulic grade per foot.	n Kutter.	C Chezy.	Air (shade).	Water.	Temp-erature.
217a	SF-42	.....	<i>Earth channels—Continued.</i>	G	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>		<i>Sq. ft.</i>	<i>Feet.</i>	<i>Cu. ft.</i>			<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	0.0293	39.2	.....	.....	Wind condition.
218a	SF-37	.....	Bear River lateral, clay, irregular.	G	.....	8.4	0.85	0.57	.....	4.79	1.69	8.08	W	.....	8.56	0.56	0.0033	0.0295	45.1	.....	.....	.....
219	H-13c	A	Bear River lateral, similar reach.	F	600.0	11.0	2.00	1.29	S	14.20	.87	7.83	W	.....	11.80	1.08	.00017	.0295	45.1	.....	.....	.....
220	H-13a	A	Billings Land & Irrigation Co., lateral 1.	G	400.0	7.5	1.25	.99	S	7.42	1.09	8.08	M-VC	d	12.35	1.15	.00029	.0299	47.8	.....	.....	D.
221	S-69	B	do.	I	930.0	95.0	1.60	.86	S	47.50	.91	43.05	M-VC	.....	8.95	.83	.00084	.0308	41.3	.....	.....	C.
222	S-72	A	Modesto main, loose sand.	D	294.9	12.0	2.70	2.30	LR	27.60	1.73	27.83	M-VC	.....	54.30	.88	.0005165	.0300	42.7	.....	.....	C.
223	S-77a	A	Upper, Riverside, sand, moss.	H	355.0	11.5	1.80	1.28	LR	14.78	1.37	23.64	M-VC	.....	12.15	1.22	.000634	.0315	50.2	.....	.....	C.
224	S-77b	A	Lower, Riverside, tangent.	H	844.4	11.5	1.80	1.50	LR	17.25	1.37	23.64	M-VC	.....	13.05	1.32	.0010647	.0318	44.4	.....	.....	C.
225a	SF-64	.....	Lower, Riverside, same, with curve.	G	.....	5.5	.61	.51	.....	2.82	.88	2.47	W	.....	5.79	.49	.0009095	.0360	39.5	.....	.....	C.
226a	W-12	B	Hyrum, gravel bed.	I	.....	24.0	.80	.50	.....	12.10	1.10	13.30	M-6	.....	25.00	.48	.0014	.0319	33.6	.....	.....	.....
227a	VMC	.....	Beasley, gravel bed, log sides.	F	1,194.0	15.4	3.20	2.38	LR	36.65	1.16	42.35	M	.....	17.78	2.05	.00026	.0321	50.0	.....	.....	.....
228a	S-9	A	Bessmer (c), loose stones.	F	1,000.0	8.0	1.70	1.23	S	9.82	1.03	10.08	M-2+8	.....	9.20	1.07	.000533	.0324	42.8	.....	.....	C.
229a	SF-55	.....	Lower, from Big Cottonwood.	H	.....	5.1	.67	.58	.....	2.97	.43	1.29	W	.....	5.70	.52	.000353	.0329	32.0	.....	.....	.....
230	S-62	A	Smithfield lateral, some cobles.	G	537.0	7.2	1.10	.81	LR	5.82	1.20	6.97	M-VC	.....	7.95	.73	.001629	.0346	34.7	.....	.....	C.
231	H-15	C	Yosemite Power Co., Golden Rock.	G	400.0	9.5	1.75	1.03	S	9.79	1.12	10.95	M-VC	.....	10.22	.96	.00093	.0349	37.3	.....	.....	.....
232a	SF-26	.....	Billings Land & Irrigation Co., lateral 1.	I	.....	21.0	1.61	1.39	.....	29.14	.84	24.59	M	.....	22.00	1.32	.00033	.0352	40.3	.....	.....	.....
233	S-18	A	Logan and Benson Ward, moss.	H	550.0	14.5	1.90	1.60	LR	23.14	1.18	27.38	M-VC	.....	17.51	1.32	.0006982	.0364	38.9	.....	.....	C.
234a	W-9	B	Hillsboro, rough.	H	.....	23.0	2.5	2.18	.....	50.10	1.44	72.00	M-6	.....	26.7	1.87	.00060	.0371	42.8	.....	.....	.....
235	S-63	B	Lateral 2½, Turlock District, sand.	G	1,020.5	23.0	3.10	1.92	S	44.26	.81	35.99	M-VC	.....	24.5	1.80	.000217	.0373	41.1	.....	.....	A.
236	S-42	A	Cochrane, gravel.	G	733.8	14.0	2.10	1.58	S	23.06	1.18	27.15	M-VC	.....	16.62	1.39	.000695	.0379	37.9	.....	.....	U.
237	S-25	A	Perrault, hard bed, grass.	H	610.0	11.5	1.60	1.15	S	13.20	.70	9.28	M-VC	.....	12.48	1.06	.000398	.0381	34.2	.....	.....	.....
238a	SF-62	.....	Hyrum lateral, rocks, moss	F	.....	6.6	1.20	.84	.....	5.55	.44	2.47	W	.....	7.20	.77	.00029	.0393	29.6	.....	.....	.....

-DESCRIPTION OF CHANNELS.

The descriptions in the following pages are to be considered as supplementary to the table beginning on page 19, which gives all the information necessary to a clear understanding of the hydraulic conditions holding at various tests with the exception of a detailed description of the channel, which would have made the table too cumbersome. The descriptions of the channels follow the same order and are numbered like those in the table, with the exception that data obtained from other sources than the work of this division are abstracted in the Appendix commencing on page 62.

CONCRETE LININGS.

No. 1, Expt. S-26, New York Canal, Payette-Boise project, U. S. Reclamation Service, Idaho. A large canal, in concrete, rough as an orange, with plastered expansion joints. Experiment rated as class C, because water issues from an open check in canal about 600 feet above station 0 and the canal passes into an earth section about 100 feet below station 6. (See Pl. I, fig. 1.) Cross sections developed from office notes of United States Reclamation Service through courtesy of W. G. Steward. Impossible to determine condition of bottom with water in canal. There is a slight curve in the reach which disturbs the filaments of current. For additional data on this canal see Nos. 2 and 3, Table I. Coefficient $n=0.0101$.

No. 11, Expt. B-4, Ridenbaugh Canal, Nampa-Meridian Irrigation District, Idaho. This test was made two years before and covered about the same reach as in test No. 13 below. Mr. Bark found a slightly lower value for slope than later experimenters, which accounts for the lower value of n found. The preponderance of evidence would indicate that a value of about 0.0125 is right for this nearly perfect piece of concrete, to include both tangents and curves. Coefficient $n=0.0110$.

No. 12, Expt. S-24. This lining in the same canal as No. 11 is a very smooth, hand-troweled, cement wash on a base of concrete $3\frac{1}{2}$ inches thick. The reach is on tangent with about a 6° curve beginning at station 9. The lining was placed in slabs 16 feet long with iron dowel pins and strips of tarred paper between slabs. After the forms were removed the joints were poured with a neat cement. As a rule the joints are as smooth to the hand as any other part of the lining (Pl. I, fig. 2), though slight cracks are opened during cold parts of the day. This is an exceptionally well-made lining, and this, coupled with the fact that the curves are spiraled into the tangents, accounts for the very low value of n as found by all experimenters. For additional experience on this canal see Nos. 11 to 15, Table I. Coefficient $n=0.0121$.

No. 13, Expt. S-24a, was made on the same canal as S-24, but the reach included not only the 901 feet of tangent as above, but also the above-mentioned curve, which was about 600 feet long, and a short reach of tangent below the curve, making the total reach 1,819 feet long. As is to be expected, the value of n is a little higher than on tangent. The slabs on curves were but 12 feet long. Coefficient $n=0.0129$.

No. 14, Expt. F-3. This experiment was made on approximately the same reach of canal as S-24, but was 1,020.6 feet long, with one slight curve in the reach. The slopes of the surface in this and experiments 26 and 28 were found by a line of levels run between the ends of reaches as usual, but the water surface was found by means of a gauge constructed on the piezometric principle. The hydraulic grade as given in the table is the mean of 23 tests. An instrument of this form should give the surface at the time of reading very closely, but the experimenter must be sure that this slope is the same as the one held at the time of the discharge measurement. Coefficient $n=0.0124$.



FIG. 1.—NEW YORK CANAL, UNITED STATES RECLAMATION SERVICE, IDAHO.
(No. 1—Downstream. Station 0 is just above meter bridge.)



FIG. 2.—RIDENBAUGH CANAL, IDAHO.
(Nos. 12-13—Upstream from Station 15.)



FIG. 3.—NORTH SIDE TWIN FALLS CANAL, IDAHO.
Note top of lining above water line. (No. 25—Downstream from Station 6.)

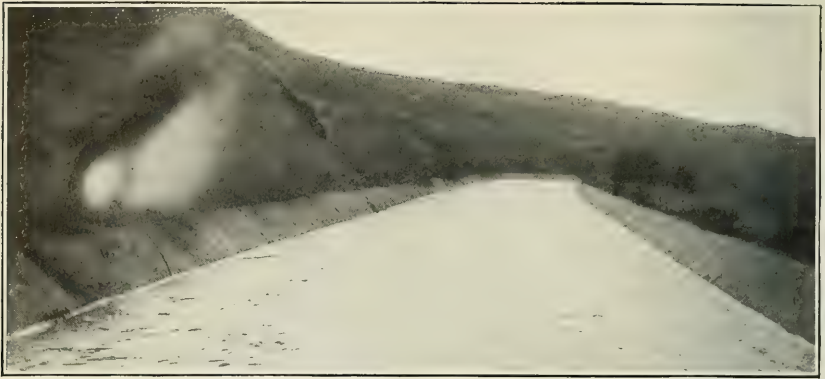


FIG. 1.—DAVIS AND WEBER COUNTIES CANAL, UTAH.

Note projecting expansion joint strips. (No. 29—Downstream from Station 2 plus 49.)



FIG. 2.—HAMILTON MILL FLUME, MONTANA.

(No. 31—Upper part of concrete section.)

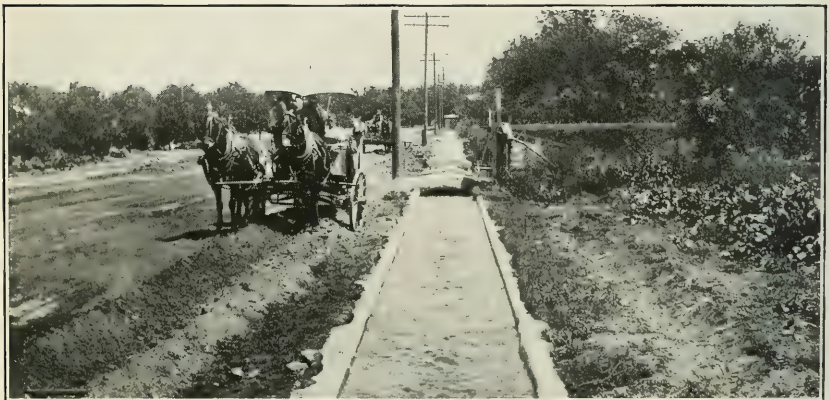


FIG. 3.—SANDERFER DITCH, CALIFORNIA.

(No. 35—Upstream from Station 3.)

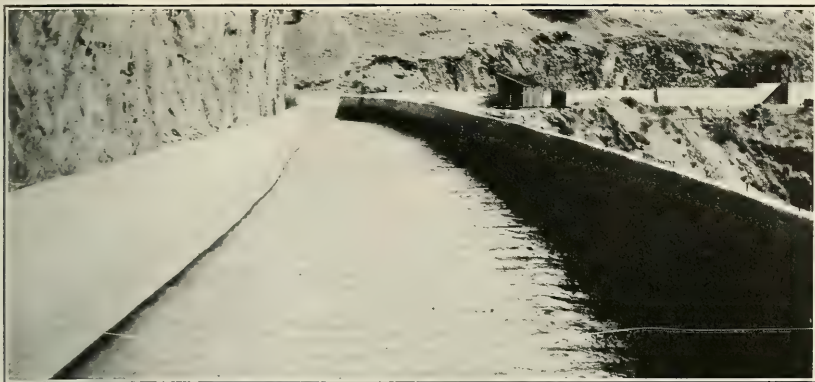


FIG. 1.—MODESTO IRRIGATION DISTRICT MAIN CANAL, CALIFORNIA.
No. 41—Upstream from Station 3 plus 64, on meter bridge.)



FIG. 2.—SANTA ANA AND ORANGE CANAL, CALIFORNIA.
Note deposit below high-water line. (No. 42—Upstream from Station 12.)

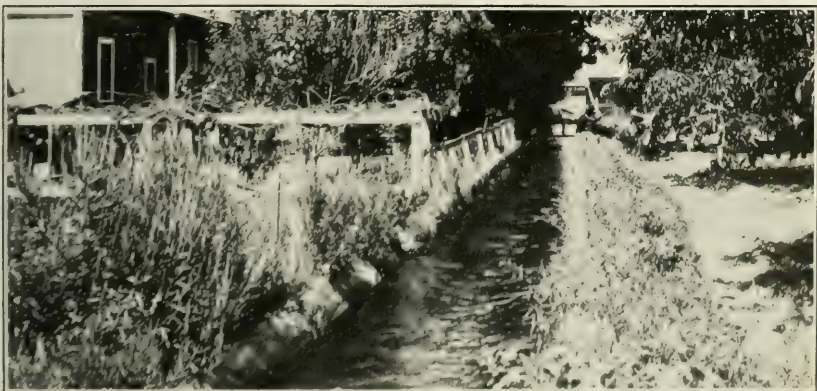


FIG. 3.—LOS NIETOS CANAL, CALIFORNIA.
Note deposit. (No. 43—Upstream from Station 1 plus 50.)

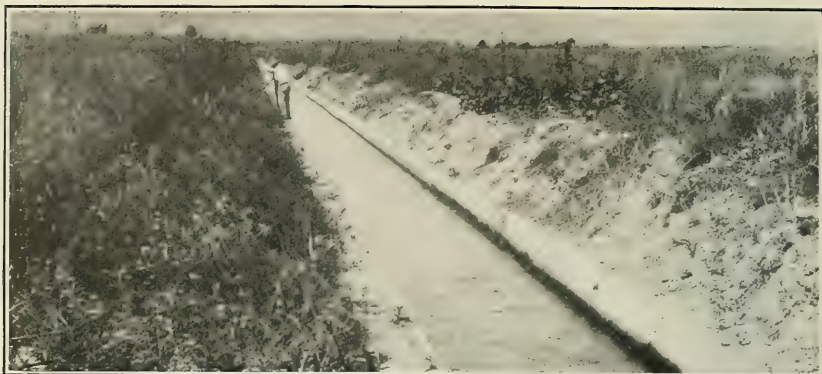


FIG. 1.—ARROYO DITCH, CALIFORNIA.
(No. 44—Upstream from Station 8.)



FIG. 2.—NORTH CANAL, BEND, OREG.
(Nos. 46, 48, and 50—Downstream from Station 5. Meter station in distance.)



FIG. 3.—MAIN CANAL, SOUTH, ORLAND PROJECT, UNITED STATES RECLAMATION SERVICE, CALIFORNIA.
Concrete section (No. 51) in distance. Earth section (No. 184) in foreground.

No. 25, Expt. S-19, North Side Twin Falls Land & Water Co.'s main canal near Milner, Idaho. As shown in Plate I, figure 3, this concrete lining fills out the main irregularities in a very rough lava-rock cut. An examination of the section below the water line was impossible at the time of making the experiment, and the various cross sections from which the value of R was deduced were taken from office notes. These covered bottom widths and elevations of the bottom at both sides and in the middle. A study of these notes shows that the bottom is undulating and that while the high velocity would prevent the accumulation of sand deposits, and lava rock does not slough off débris to any extent, yet the velocity is retarded by the disturbance in the filaments of current due to the undulations. Coefficient $n=0.0138$.

No. 26, Expt. F-1, Davis and Weber Counties Canal, Utah. This experiment was conducted in the same canal as tests Nos. 28 and 29, but about 8 miles upstream and about 1 mile below the head gate from the river. Condition of bottom could not be determined, but was probably about the same as in No. 28. The concrete on sides was smooth and unbroken. The hydraulic grade was taken as the mean of five tests with level and piezometer and found to be 0.000413, while constructed grade of this portion of canal was 0.000445. Coefficient $n=0.014$.

No. 27, McL., Davis and Weber Counties Canal, Utah. See Nos. 26-28-29. Coefficient $n=0.0144$.

No. 28, Expt. F-2. This experiment was on a reach 468.5 feet long, which was included in the reach 1,000 feet long described in No. 26. The hydraulic grade was taken as the mean of level lines run between 12 settings of the piezometer instrument spoken of under No. 14. The mean of these 12 observations gave a slope of 0.0006168, while the constructed grade of the canal, as stated by the chief engineer, was 0.000626, and in No. 29 the writer found the surface slope to be 0.000629. In the description of conditions B. P. Fleming states that the patches of gravel consisted of all sizes up to 5 inches in greatest dimension and that probably 10 per cent of the area was covered with them, mostly adjoining the toes of the side slopes. This experiment was made about six weeks after No. 26. Coefficient $n=0.0146$.

No. 29, Expt. S-13, Davis and Weber Counties Canal, Utah. This canal furnishes an example of the retarding effect of wooden expansion joints if they are not so set that they can not project into the canal section (Pl. II, fig. 1). The lining was laid in slabs varying in width from 8 to 16 feet. Strips of wood a little larger than building lath were placed between the slabs with the idea that they would eventually be pulled and the space filled with asphalt. This has not been done, and at present the strips project from 0 to $1\frac{1}{2}$ inches into the section. However, the velocity at the bottom was retarded by small patches of gravel which have probably sloughed off the hillside cut in which the canal runs. This condition will probably be present each season, even though the canal be cleaned out once a year, but the friction factor n can undoubtedly be reduced one or two units in the third decimal place by carrying out the original idea contemplated in the construction. Coefficient $n=0.0154$.

No. 30, B-10, King Hill Canal, Idaho. This test was made on a reach covering both tangent and curves. The concrete was not surfaced, but left as hand tamped to grade. After surface coat had set, the 2 by 4 inch end forms were removed and the groove poured with a 1 to 1 mixture of sand and cement. The surface is described as quite rough, especially at the joints. The canal was clean of detritus and moss. Coefficient $n=0.0143$.

No. 31, H-29, Hamilton flour mill flume, Montana. This flume was constructed recently of a 1 to 7 mixture of cement and sand with some fine gravel. The coat has a few blowholes, but is usually smooth. The concrete was deposited against wood forms and not plastered. The alignment is as follows: 10° curves at stations 4 and 6. Small curves at stations 8+50, 11, 14, and 20+50. The rest of the distance was on tangent (Pl. II, fig. 2). Coefficient $n=0.0149$.

No. 35, Expt. S-69, Sanderfer Ditch Co.'s main canal, near Whittier, Cal. As shown in Plate II, figure 3, this reach is straight and quite uniform. The bottom is slightly dished. As is the case of all small lined ditches in southern California, the sides and bottom are covered with a rough deposit which entirely vitiates the good results which would be anticipated by using a smooth cement wash such as the one on this ditch. This deposit appears to accumulate on either smooth or rough concrete, so the added expense of the former does not appear to be warranted in view of the results. The water in this ditch was clear and did not carry an appreciable amount of sand. Coefficient $n=0.0155$.

No. 37, Expt. S-37a, lateral 12, Orland project, United States Reclamation Service, central California. This is a small lined section of general trapezoidal form, but with a slight dishing in the bottom. About 50 feet above station 0 is the lower end of a chute drop, and the ditch below station 2 plus 06. turns to the right 90° in a curve of 34 feet radius. The surface of the channel was a good grade of concrete, but not smooth washed. There was a slight deposit of slimy silt, which would have allowed a low value of n but for gravel scattered throughout the ditch section, which had a great influence on velocity, as the section is small. Coefficient $n=0.0160$.

No. 38, Expt. S-37. This experiment is on the same lateral as No. 37 but covers a straight reach immediately below the right-angle curve noted above. In the opinion of the writer the value of n in this experiment is better for the gravel condition in a small lined section than that found in the shorter reach used for No. 37. This gravel ranged in size from fine to that of a walnut and had a marked influence in retarding the velocity, as there was more or less movement of the gravel down the channel, which retards velocity more than does stationary gravel. Coefficient $n=0.0192$.

No. 40, Expt. S-11, South Cottonwood Ward Canal, near Murray, Utah. This is a lined stretch about 450 feet long between an earth section, and a wooden flume. There is a slight curve at the upper end. A deposit of about 0.07 foot of fine sand and rootlike growths covered the bottom and modified the original section of rather rough concrete. A slight deposit of moss and slime also modified the sides of the channel. A reach 350 feet long was chosen in the middle of the lined stretch. Coefficient $n=0.0171$.

No. 41, Expt. S-55, Modesto Irrigation District main canal, near Lagrange, Cal. As shown in Plate III, figure 1, this reach of canal is on an approximate tangent. There is a very sharp curve about 50 feet below the reach tested. The lining is a very good grade of concrete, being about as rough as an orange. For the small amount of water in the canal when tested the value of n is high, because of the presence of a number of pieces of slate rock that have fallen into the canal from the adjoining cliffs. This influence would probably be materially reduced when the canal is carrying water to capacity. However, this experiment shows the value of cleaning the canal as often as practicable in order to maintain a high carrying capacity which is much desired by this district. Coefficient $n=0.0174$.

No. 42, Expt. S-63, Santa Ana and Orange Canal, near Orange, Cal. In the reach tested, 1,082.8 feet, there was a gentle curve between stations 5 and 7. As shown in Plate III, figure 2, which was photographed from a position about 200 feet below station 10, this canal has the rough deposit and moss common to southern California ditches. In addition the concrete lining of the bottom has been completely covered by a deposit of soft sand from 0.1 to 0.2 foot deep. The carrying capacity of such ditches could be materially increased by the introduction of numerous sand gates of some form. This lining had originally been a reasonably smooth piece of work, but the deposits had destroyed much of the usefulness of the smooth concrete. Coefficient $n=0.0176$.

No. 43, Expt. S-70, Los Nietos Water Co.'s main canal, near Whittier, Cal. The surface of the original lining in this canal is fairly smooth, but the deposit common to this region has so changed its character that, aided by the rolling sand, a high value of n is

found. This sand was about 0.03 foot deep. The clear water emerges quietly from the lower end of a siphon under a road about 100 feet above station 0. The canal turns at right angles, without curvature, about 100 feet below station 6. However, the depth at the various cross sections remains quite constant, showing that the water was not appreciably checked up by this turn. As shown in Plate III, figure 3, there was a very slight retarding effect due to grass and weeds dragging on the surface of the water near the edges of the channel. Coefficient $n=0.0188$.

No. 44, Expt. S-67, Arroyo Ditch & Water Co.'s main canal, near Whittier, Cal. As shown in Plate IV, figure 1, this rough-finish concrete section has accumulated a deposit of rough mossy growth that greatly retards the velocity of the water. In a few places throughout the reach tested the lining was irregular and not in true alignment, which also tended to increase the value of n . The reach was on tangent, with a sharp angle about 50 feet above station 0 and a gentle curve about 100 feet below station 10. See discussion under Nos. 35, 40, and 42, above. Coefficient $n=0.0188$.

Nos. 45 to 50, Expts. S-31, S-30, S-32, Central Oregon Irrigation Co.'s North Canal near Bend, Oreg. These experiments were conducted with varying discharges, on consecutive days, in identical reaches; (a) is on a tangent 240 feet long between a 15° curve above and a 14° curve below; (b) embraces 157 feet of tangent, then 154 feet of 14° curve to the right, then 90 feet tangent, then 109 feet of 15° curve to the left, then the tangent that includes (a) 240 feet long, then 178 feet of 14° curve which passes into a very rough lava-rock cut about 200 feet below station 10 plus 26.

This lining is a clean-scoured, very rough, and deeply pitted concrete made in a rough lava-rock cut. As shown on Plate IV, figure 2, the cross sectional form is even and the filaments of current are not disturbed except by the curves, but the inherent roughness of the lining accounts for the high values of n . The grade of the bottom of this canal was constructed 0.001 feet per foot.

This lining was a 1 : 4 : 5 mixture, deposited behind shiplap forms against a hand-laid rock wall, filling the cavities in a rough rock cut. Expansion joints of $\frac{1}{2}$ by 4-inch lumber were placed on sides and bottom every 12 feet and left in the concrete.

No. 51, Expt. S-38, main canal, South Orland project, United States Reclamation Service, California. As shown in Plate IV, figure 3, this lined section comes between two earth sections of the canal. The concrete is quite rough and pitted, with slight growths of moss, but not nearly sufficient to account for the high value of n found. The writer can only account for this value because of retarding influences due to the earth channel below the lined reach. Coefficient $n=0.0211$.

No. 53, Expt. S-68, small ditch from pumping plant, California. Although constructed with a smooth-finished cement wash, this ditch shows a high value of n because a dark, crinkly deposit has changed the condition of the walls. Vegetation on the banks dragged in the water and retarded velocity to a slight extent (Pl. V, fig. 1.) This test is not given full weight because the ditch is too small to give a first-class current-meter measurement. The mean of three measurements was used. Coefficient $n=0.0220$.

No. 54, Expt. S-75, Riverside Water Co.'s Lower Canal, Riverside, Cal. This experiment gives a good example of a cement-wash lining in which under favorable conditions in southern California a friction factor of about 0.018 might be expected without eradicating the sand which appears to be ever present in the canals in this vicinity. If the sand were removed by the addition of numerous sand sumps and gates this factor would be reduced to 0.016 or thereabouts. At the time of making the tests on this canal, as shown in Plate V, figure 2, the lining had been broken in scattered spots, allowing vegetation to root and grow. In the bottom of the channel were scattered deposits of loose sand, covering possibly 10 per cent of the bottom area. In some of these deposits moss and water grasses flourished. A gentle curve about 100 feet above station 0 had little or no influence on the flow in the low velocities en-

countered. This lining was a cement and sand coat about 1 inch thick, applied directly to the trimmed surface of the earth channel. Occasional fractures in such a lining are to be expected. Coefficient $n=0.0221$.

No. 55, Expt. S-71, Riverside Water Co.'s Upper Canal, in Riverside, Cal. While originally a canal lined with a well-built and but lightly pitted cement-wash surface the bottom of the channel has completely lost its identity as a concrete lining in so far as friction is concerned, since there is now more than 18 inches of sand in the bottom. This drifts down the canal in little pockets that look like hoof prints of stock. The positions of these shift rapidly, causing the depth of water at a given point to change 0.4 or 0.5 foot in about 30 minutes. This condition renders a measurement by current meter using multiple points obviously inaccurate, and the writer used the integration method, as the latter will give results as close to those found by multiple points as can be desired. A measurement by this method takes but a few minutes, and the canal bottom in this period probably does not shift sufficiently to vitiate the results. As shown in Plate V, figure 3, there are no curves or structures above the reach tested to change results, and the same condition holds downstream. Coefficient $n=0.0231$.

WOODEN FLUMES.

No. 57, Expt. S-50, Reno Ditch, Reno Light & Power Co., Nevada. This flume is built of 2 by 12-inch surface pine with all cracks battened with 1 by 4-inch strips. This gives a retarding vertical batten about every 12 feet. As shown in Plate VI, figure 1, the flume leads from the cobble-lined ditch, No. 254, to the penstock above the power house. The reach chosen begins about 100 feet below the upper end of flume and extends for 800 feet down a tangent and around part of a gentle curve to a point about 800 feet above the penstock. Coefficient $n=0.0103$.

No. 58, Expt. H-30, Bitter Root Valley Irrigation Co.'s Canal, Montana. This straight flume is built of 2½-inch tongued and grooved finished siding, with butt joints calked with oakum. The interior was therefore free from battens or other retarding construction. Station 0 was about 100 feet below the flume intake from an earth canal. Station 5 is about 50 feet above a trash rack which was clean at the time of measurement and does not appear to effect the flow. Coefficient $n=0.0112$.

No. 59, Expt. B-11, King Hill flume, Idaho. This test was conducted August 7, 1911, in a flume lined with a very smooth roofing material, which was placed in the spring of that year. Longitudinal wooden strips worn very smooth by the water, held the roofing in place. Coefficient $n=0.0115$.

No. 64, Expt. S-34, Big flume, Central Oregon Irrigation Co. near Bend, Oreg. As shown in Plate VI, figure 2, this flume is very sinuous, the reach of 1,100 feet tested having an alignment as follows: Station 0-60 being at the P. T. of a 12° curve right; thence on tangent 329.9 feet; thence around a 20° curve right, 135 feet; thence reversing into a 20½° curve left for 256.1 feet; thence reversing again (at a point near the ladder, in the figure) into a 17½° curve 211.7 feet; thence on a tangent for the balance of the reach, 107.3 feet. The flume was originally constructed of surfaced and sized 2 by 12-inch pine, with cracks battened with ½ by 3-inch strips surfaced on one side and both edges. A washout necessitated rebuilding the flume in part, and a few of the planks and battens in the rebuilt portion were not surfaced. It is a difficult matter to tell one from the other after a few months' use, as a slight deposit of green slime makes the boards very smooth indeed. Bifurcation works divide the water about 200 feet below station 11. The constructed grade was 10.56 feet per mile, or 0.002 feet per foot. Coefficient $n=0.0117$.

Nos. 65, 66, 67, 68, H-16, Alkali Creek flume, Billings Land & Irrigation Co., Montana. Four tests were made in a straight reach of this flume, which is of unsurfaced lumber, somewhat waterworn and with slight deposits of slime and moss. The grade of the bottom is excessive and irregular, causing extensive wave action when oper-



FIG. 1.—SMALL DITCH NEAR WHITTIER, CAL.
Clear water filling concrete section. (No. 53—View upstream from Station 2.)



FIG. 2.—LOWER CANAL, RIVERSIDE, CAL.
Note weeds in broken places. (No. 54—Upstream from Station 2.)



FIG. 3.—UPPER CANAL, RIVERSIDE, CAL.
Note meter station. (No. 55—Upstream from Station 3 plus 30.)



FIG. 1.—RENO DITCH, NEVADA.
(No. 57—Looking downstream into flume. Penstock in distance.)

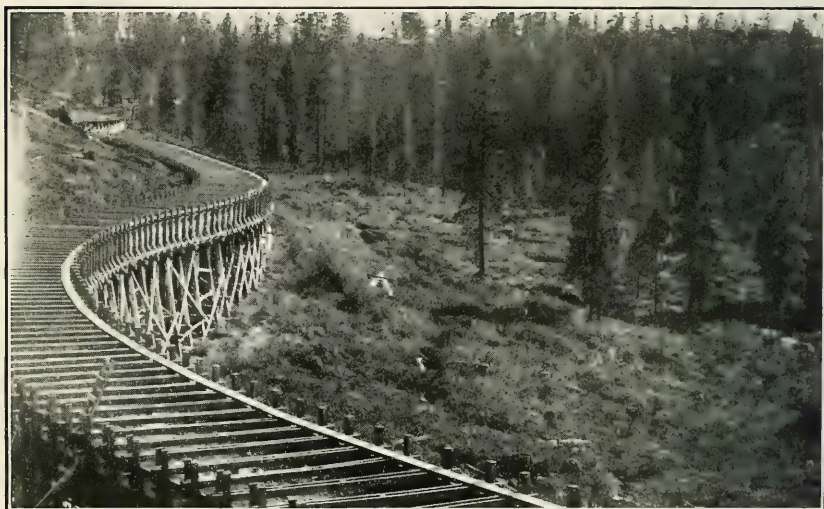


FIG. 2.—BIG FLUME NEAR BEND, OREG.
(No. 64—Upstream from Station 8.)

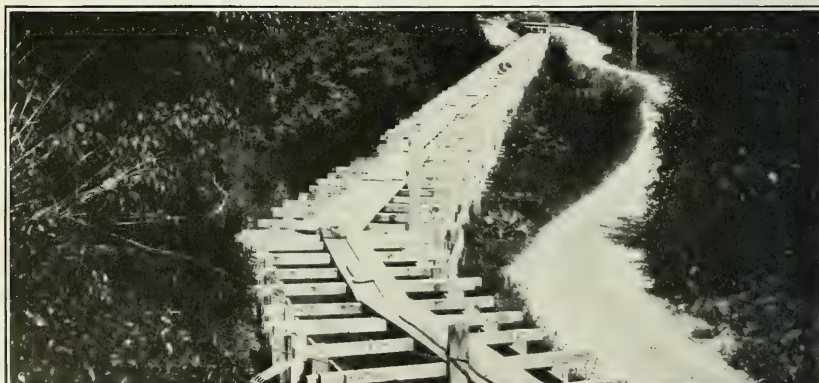


FIG. 3.—TELLURIDE FLUME, UTAH.
(No. 75.) The reach tested was tangent shown. Note sharp angle at bend.)



FIG. 1.—ARNOLD FLUME, OREGON.

(Nos. 77 to 80, inclusive—Taken when new. Note battens.)



FIG. 2.—ARNOLD FLUME NEAR BEND, OREG.

(Nos. 77 to 80, inclusive—Upstream past Meter Station 15 plus 81.)

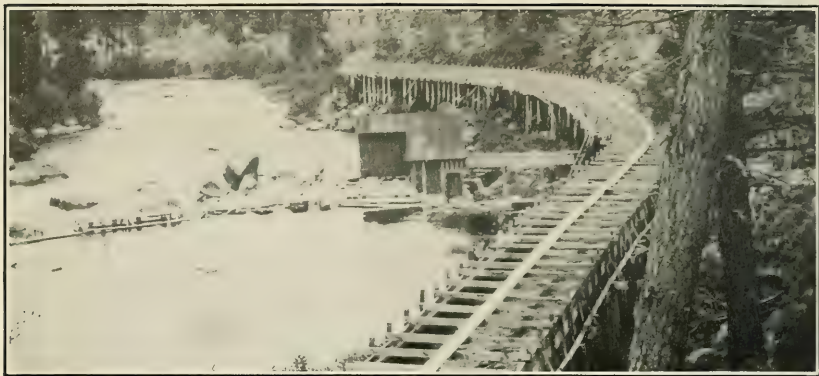


FIG. 1.—SWALLEY DITCH FLUME, OREGON.

(Nos. 84 to 87, inclusive—Downstream from Station 0. Total reach extends to distant tangent.)

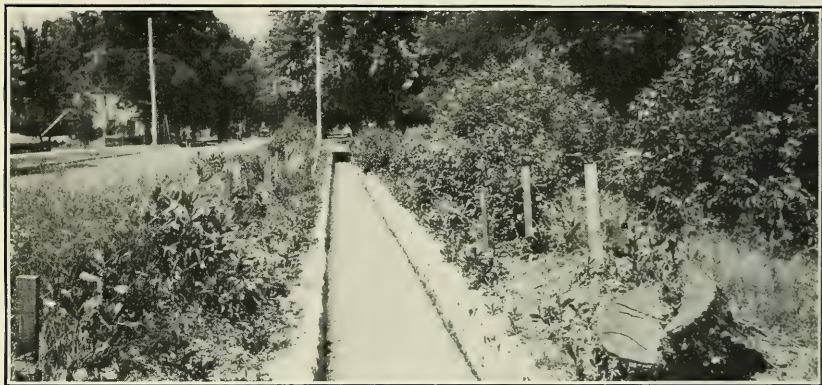


FIG. 2.—JACOBS DITCH, BOISE, IDAHO.

Note trash rack at culvert. (No. 113—Downstream from Station 0.)



FIG. 3.—JACOBS DITCH, IDAHO

Note unplastered walls. (No. 115—Upstream from Station 1.)

ated to capacity. The flume has been in use nine years, and the inside relined with 1-inch lumber meanwhile. Mr. Harding suggested in designing a flume where such waves are to be expected, that a liberal freeboard be allowed for or else that the crests of the waves be considered the water surface. He has solved n for both assumptions and finds n runs about 0.004 higher where crests are considered the water surface. This difference was quite close throughout the four tests.

No. 70, Expt. H-39, Bitter Root Valley Irrigation Co.'s flume No. 2, Montana. This flume is built of 2½-inch finished tongued and grooved siding. The side boards are 12 inches wide, with the cracks battened with ½ by 2-inch strips. On each side of the cracks in the bottom is laid a ½ by 1-inch strip, leaving a groove about one-half inch wide over the crack. This groove is then poured with an asphaltic filler. The reach chosen follows a contour with the following alignment: Station 0 about 100 feet below upper end of flume; thence 100 feet of about 10° curve right; thence 200 feet tangent; thence 100 feet of about 5° curve right; thence 100 feet tangent; thence 50 feet of about 10° curve left; thence 100 feet tangent to a small bend; thence 50 feet tangent, to end of reach which is about 150 feet above outlet to flume. This reach is very similar to that of No. 71. Coefficient $n=0.0125$.

No. 71, Expt. H-37, Bitter Root Valley Irrigation Co.'s flume No. 1, Montana. The reach tested is at the lower end of a flume about 1 mile long. The sides were formed of 2½ by 12-inch finished, tongued and grooved lumber with cracks battened with ½ by 1½-inch strips. There are no battens on the bottom. There was a thin coating of sand and gravel in places. The alignment is about as follows: Station 0 to 1 is about 20° curve right; thence 200 feet tangent; thence 300 feet of about 10° curve left; thence 200 feet tangent; thence 50 feet of about 20° curve left; thence 150 feet tangent. The value of n should be compared with those found in Nos. 58, 70, 73. It is higher than for No. 58, because the latter is on a clean tangent. It is lower than for No. 73, which is on a very crooked reach. Coefficient $n=0.0127$.

No. 72, Expt. H-28, Hedge Canal, Bitter Root Stock Farm, Montana. This test is on a new reach of flume built of 3 by 12-inch finished tongued and grooved lumber. The canal is rough both above and below the flume, which is too short for the best grade of results. Coefficient $n=0.0129$.

No. 73, Expt. H-32, flume No. 7 of the Bitter Root Valley Irrigation Co.'s main canal, Montana. This is a very crooked flume of the same construction as in No. 58. There was no moss or gravel. The flume follows mountain contours, having sharp curves right and left, with short tangents between. The higher value of n found in this test is to be expected and gives comparative results between straight and very crooked flumes, when compared with the three other tests on flumes of this canal. Coefficient $n=0.0135$.

No. 74, Expt. H-11, lateral No. 4, Billings Land and Irrigation Co., Montana. This is a small flume 2 feet wide and 2 feet deep. There are no battens and the butt joints are calked with oakum. The inside of the flume is weathered, but appears to have been originally of surfaced material. The flume is generally straight, there being wavy places which slightly distort the true alignment. The ends of the reach are far enough from entrance and exit to the flume to be uninfluenced. Coefficient $n=0.0138$.

No. 75, Expt. S-16, Telluride flume, Utah Power & Light Co., near Logan, Utah. This test is on a straight reach of flume with an angle of about 20° left, located 35 feet below the end of the reach. See Plate VI, figure 3. The sides are of 1-inch Oregon pine with all cracks battened with ¾ by 3-inch strips, the vertical battens, about 16 feet apart, being beveled on the upstream edge to reduce friction. The bottom battens appear to be about 6 inches wide, but examination was difficult. All surfaces of wood in contact with water appear to have been surfaced, but are so weathered and waterworn that this point is indeterminate. Coefficient $n=0.0141$.

Nos. 77, 78, 79, 80, Expts. S-35, a, b, c, Arnold flume, Central Oregon Irrigation Co., near Bend, Oreg. Tests were made on various sections of this flume, covering curves and tangent and both. The flume shown in Plate VII, figures 1 and 2, is about 3 years old and was constructed of green pine lumber, with cracks battened with 1 by 4-inch strips in the first 400 feet of the total reach and with 1 by 6-inch strips in the lower part.

Test S-35 covers the whole reach 2,200 feet long, embracing 437 feet of 15° curve, then 1,147 feet of tangent shown in figure 2; then 616 feet of 20° curve with a short tangent at the lower end. Test lettered "a" covers the same 15° curve, "b" covers the long tangent, and test "c" covers the 20° curve and the short tangent. The value of n should have been lowest on the long tangent when judged by the appearance of the channel.

No. 82, Expt. H-22, Hedge Canal, Bitter Root Stock Farm, Montana. The portion of this flume tested is about 14 years old. The lining is 3-inch tongued and grooved lumber, surfaced on the water side. There is no moss and only an occasional piece of gravel. The flume follows a mountain contour with heavy curvature, brought about with chords 16 feet in length. This accounts for the rather high value of n . Coefficient $n=0.0153$.

No. 83, Expt. H-24, Hedge Canal, Bitter Root Stock Farm, Montana. This flume is of the same age and general description as that tested in No. 82. It is clean of gravel except on the inside of curves. Coefficient $n=0.0155$.

Nos. 84, 85, 86, 87, Expt. S-33, Swalley Ditch near Bend, Oreg. This flume (shown in Pl. VIII, fig. 1) is of rough pine lumber with $\frac{1}{2}$ by 4-inch battens on all cracks. It is weathered, but not made as smooth as if originally surfaced. There is a small amount of slime present. Reach (a) is on the first tangent in the view. Coefficient $n=0.0157$. Reach (b) covers the last 35 feet of the tangent in the view then around the curve to the left. Coefficient $n=0.0149$. Reach (c) covers the second tangent and the sharp curve, of about 75 feet radius, to the right. Coefficient $n=0.0157$. Reach (d) covers all of the above reaches. Coefficient $n=0.156$.

No. 88, Expt. S-61, Golden Rock Lower Ditch, Yosemite Power Co., California. This test was made on a reach of flume made of unplanned pine lumber $1\frac{1}{2}$ by 15 inches. There were three battens in the bottom, each $\frac{1}{2}$ by 4 inches. There were no battens on the side within the water section. The water was clear. There was no perceptible growth or slime on the wood. No structures were within a reasonable distance of the reach chosen, although a gentle curve ended about 30 feet above station 0. Coefficient $n=0.0159$.

No. 89, Expt. S-58, Modesto Irrigation District main canal, California. This wooden flume, built of 2 by 12-inch lumber, is battened with 1 by 4-inch ship-lap with the groove on top. The latter is then poured with asphalt. There are no battens on the bottom, which was covered with about one-half inch of sand. The dripping asphalt had rendered the sides quite rough, and the value of n found is about what might be expected. The flume is straight, with water in the lower end falling over check boards. For this reason and since the water raised in the canal about 0.2 foot during the measurement, the writer has classed this test B. There was no growth or slime noticeable. Coefficient $n=0.0163$.

No. 90, Expt. S-6, lateral of Jordan and Salt Lake City Canal near Salt Lake City. This covers a straight stretch of old flume of rough lumber. There are no battens in the bottom, but the first batten up on the sides was sometimes in and sometimes out of the water through the reach tested. There was no slime, gravel, or moss present, but the flume was wavy, and the bottom on a wavy gradient. There was a sharp turn without curvature about 150 feet below station 4. Coefficient $n=0.0167$.

No. 91, Expt. S-48, Wheeler Ditch near Reno, Nev. This flume is made of 2 by 14 inch rough pine lumber with 1 by 6 inch battens. There are occasional deposits

of gravel, and the sides are slightly waterworn and have a slick deposit of silt. A sharp curve occurs about 50 feet above station 0, but the reach tested is practically straight. Coefficient $n=0.0167$.

No. 93, Expt. G-3, Roller flume, Louisiana. This flume was about 14 years old, with the exception of a portion of the reach tested, about 75 feet long, which had been repaired with new cypress lumber. The original lumber was unsurfaced, but at present is covered with a slimy growth. The lumber was parallel to the axis of the canal, but the surface was slightly irregular. Coefficient $n=0.0191$.

No. 94, Expt. S-76, Riverside Water Co.'s Lower Canal near Riverside, Cal. The side boards of this flume were of vertical tongued and grooved lumber, making a very rough interior. The bottom was painted with a tar or asphalt product, and the posts were in such condition that the flume sagged and was out of line in numerous places. The value of n as found for this flume may be taken as that of a flume in exceedingly poor condition but without appreciable deposits of sand or gravel. It is understood the company expects to replace this flume in the near future. The reach tested is straight. Water enters from a cement-lined section about 50 feet above station 0 and leaves the flume into an earth ditch about 50 feet below station 7 plus 46. Coefficient $n=0.0196$.

No. 96, Expt. S-65, Fullerton Ditch of the Anaheim-Union Water Co., California. This flume has the bottom so covered with soft sand that it classes more nearly with an earth section. The lumber was unsurfaced, and a growth of moss retards velocity for about 0.1 foot from each side. The reach tested was straight, but there is a sharp curve about 50 feet above station 0 where the earth canal joins the flume section. About 15 feet below station 6 plus 72 the water enters the earth section again. Coefficient $n=0.0202$.

MASONRY-LINED CHANNELS.

No. 113, Expt. S-29, Jacobs Ditch, Boise, Idaho. This test is on a straight stretch of ditch. As shown in Plate VIII, figure 2, the sides are of first-class rubble masonry with all cracks smoothly plastered with cement. The bottom is smooth cement lining laid like a good grade of sidewalk. About 50 feet below the lower end of the reach the ditch passed through a vertical trash grating, where there was a loss of head of about 0.05 foot. This grating was kept clean of debris during the test. Coefficient $n=0.0130$.

No. 115, Expt. S-27. This test was made on the same ditch as No. 113 above, but this reach is lined on both sides and bottom with dry laid, unchinked rubble, as shown in Plate VIII, figure 3. The bottom is quite irregular, with scattered loose cobbles. A clean grating came a short distance below the reach, as in No. 113. Coefficient $n=0.0235$.

No. 116, Expt. S-28. This test also is on the same ditch as No. 113 above. This reach, one city square long, came between the reaches in No. 113 and No. 115 above. It appeared to have been originally like No. 113, except that the bottom was not lined. There were several cobbles throughout the bottom of this reach, and this probably accounts for the fact that the value of n is slightly higher than for No. 115, while to all appearances it should have been slightly lower. A grating similar to the ones noted above came below the lower end of the reach. Coefficient $n=0.0250$.

No. 117, Expt. S-45, Orr Ditch, Reno, Nev. As shown in Plate IX, figure 1, the sides are quite smoothly built rubble, with most of the cracks well plastered, but the bottom is covered with shifting sand and loose cobbles so that, if lined, the lining is completely concealed. The lined section ends shortly below the lower end of this reach, passing into an earth channel. This test exemplifies the need of keeping sand and gravel from a lined section if the low value of n that might be expected is to be realized. Coefficient $n=0.0298$.

EARTH CHANNELS.

No. 119, Expt. S-2, Farmers' (Tristate) Canal, Nebraska. This test and also No. 120 are on long, straight reaches of a large canal, constructed in Brule clay. An engineer connected with the original construction states that in the original design the value of n was estimated as 0.025, but, as shown in Plate IX, figure 2, the canal is running to but partial capacity, and the mean velocity is almost sufficient to scour the material. It had one riffle midway of its length, due to old bridge approaches jutting into the canal. The values of n in Nos. 118, 119, and 120 are comparable, as the Interstate Canal is in the neighborhood of the Tristate. A fringe of grass extends along the edge but retards only a very small part of the flow. The bottom is extremely even, smooth, and hard, and with the addition of a coating of sediment from the murky waters of the North Platte River, appears to be very efficient. Gentle curves adjoin both upper and lower ends of the reach. For further notes see No. 120. Coefficient $n=0.0130$.

No. 120, Expt. S-1, Farmers' (Tristate) Canal, Nebraska. This reach (Pl. IX, figs. 2 and 3) was perfectly clean cut throughout its length, and in the opinion of the writer gives the better value of n than reach in No. 119. In both tests the fall is slight, and the mean value of the results of several tests with the level was accepted. The reach is a tangent between two gentle curves. The bottom was as described in No. 119. Coefficient $n=0.0164$.

No. 126, Expt. S-83, Maricopa Canal, Salt River project, United States Reclamation Service. This reach was part of a long stretch of canal with a clean, sandy bottom and a slight fringe of grass along the edge, but the influence of the latter was practicably negligible (Pl. X, fig. 1). The slope is very gentle, so that a very slight error in the levels would appreciably affect the value of n . The measurement with current meter was made above the section tested, where the velocity was greater. Coefficient $n=0.0166$.

No. 127, Expt. S-3, Winter Creek Ditch, Nebraska. This test was made on a long, straight reach of ditch, with very clean, hard bottom, in a cemented material. A fringe of grass bordered both edges. A stiff wind was blowing directly down stream during the test, and a value of n of 0.0180 is probably better for this canal under normal conditions than that actually found by the measurement made. Coefficient $n=0.0170$.

No. 130, Expt. H-7, Billings Land & Irrigation Co.'s Canal, Montana. This test was made on a straight reach of canal excavated in clay loam soil. The little grass at the edges is of slight consequence, as the bottom is slick, though roughed by cutting in places. The mean velocity, 2.45 feet per second, was about the limit, as cutting was taking place where the bottom was not protected with a deposit of gravel. A downstream wind probably reduces the value of n from about 0.018, making it quite comparable with No. 127 above. Coefficient $n=0.0174$.

No. 132, Expt. H-5b, Cove Ditch, Montana. This test is on the same ditch, with same channel conditions as No. 133. This reach is all curve, the first 300 feet being on a 30° curve, while the ensuing 300 feet is on a reverse 30° curve. While the slopes and cross sections are quite different, the value of n for this test and for No. 133 agree quite closely. Coefficient $n=0.0180$.

No. 133, Expt. H-5a, Cove Ditch, Montana. This reach is part tangent (station 0 to station 2) and part on a 20° curve (stations 2 to 4). The ditch is 6 years old. Originally excavated in sandy loam soil, the bottom is now covered with a silt deposit. A fringe of grass retards the velocity at the edge, but not the main flow. Coefficient $n=0.0186$.

No. 134, Expt. H-19, Billings Land & Irrigation Co.'s main canal, Montana. This reach of canal follows a gentle hillside contour, although practically straight. There is a little sand and fine gravel scattered over a general bottom of clean soil. The



FIG. 1.—ORR DITCH, RENO, NEV.

(No. 117—Upstream from Station 1 plus 30. Station 0 is at bridge shown.)



FIG. 2.—FARMERS' (TRISTATE) CANAL, NEBRASKA.

(No. 120—Downstream past Meter Station 6.)



FIG. 3.—FARMERS' (TRISTATE) CANAL, NEBRASKA.

(No. 120—Portable rating car and meter station.)



FIG. 1.—MARICOPA CANAL, UNITED STATES RECLAMATION SERVICE, ARIZONA.
(No. 126—Downstream from Station 0.)



FIG. 2.—GRAND CANAL, UNITED STATES RECLAMATION SERVICE, ARIZONA.
(No. 135—Upstream from Station 10.)



FIG. 3.—LATERAL 7, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.
Note general high-water line. (No. 149—Downstream from Station 0.)



FIG. 1.—HEDGE CANAL, MONTANA. (No. 161.)



FIG. 2.—BIRCH CANAL, IMPERIAL VALLEY, CALIFORNIA.
(No. 162—Downstream from Meter Station 6.)



FIG. 1.—CROWLEY CANAL, LOUISIANA.
(No. 164—Upstream from meter station.)



FIG. 2.—SANTA ANA AND ORANGE CANAL, CALIFORNIA, JUST AFTER CLEANING.
(No. 172—Upstream from Station 10.)



FIG. 3.—CENTRAL MAIN CANAL, IMPERIAL VALLEY, CALIFORNIA.
(No. 173—Downstream. Portable rating car over Station 0.)

velocity in this canal (mean 2.30 feet per second) appears to be about right for this soil, as the middle of the section is clean without cutting and there is a slight deposit of silt and mud along the sides. A downstream wind perhaps gives a value of n slightly below what might be expected. Coefficient $n=0.0181$.

No. 135 Expt. S-82, Grand Canal, Salt River project, United States Reclamation Service. This reach covers a clean-cut stretch, straight except for a gentle curve about 250 feet long, shown in Plate X, figure 2. Originally excavated in a clay loam soil, the section now has a deposit of clean sand in the middle and slick, silty mud near the sides. The fringe of grass shown in the view is slightly above the general highwater mark and had little influence on the reach when tested. Coefficient $n=0.0183$.

Nos. 137, 138, 139, and 140, Expts. H-18, Billings Land & Irrigation Co., Montana. These tests were made on the same reach of ditch, with varying discharges of water. The reach is straight, with a curve nearly adjoining each end. The bottom of the canal, which was originally excavated in Benton shale, is covered with fine sand. The shale at the sides has broken to a fine, slick clay. The cross section is quite regular. Although the discharge varied from 92 to 172 second-feet, the value of n does not vary materially. The tests are lettered in order, a, b, c, and d. After the first two tests a slide came into the canal below the reach tested and had the effect of checking up the water so that the slope was quite different between tests a, b, and c, d. The slide, of course, caused the area of the water section at the lower end to exceed that at the upper end, hence changing the velocity and necessitating a correction for change in velocity head. Cross winds, which were blowing during tests c and d, might easily have effected the slope sufficiently to account for the variation in the value of n . These four tests would not be considered as showing that there is any variation in n with a variation in the value of R, or V.

No. 141 Expt. H-6, Billings Land & Irrigation Co., Montana. This test was made on a straight reach, between gentle curves. The canal, originally excavated in Billings clay, is generally clean, but has a little fine gravel in the bed and some fine silt deposit near the sides. A few cattle tracks and a little grass had a slight retarding effect near the sides, but did not effect the main flow. Coefficient $n=0.0188$.

No. 142, Expt. S-87, Maxwell Ditch, Colorado. This ditch follows a mountain contour. The sides were rather irregular, with a fringe of grass, while the bottom was free from growth and covered with sand and fragments of rock, while the low velocity allowed a silt deposit near the banks. The slope is so gentle that a very small error in levels would materially effect the value of n . For this reason the writer has given but a B rating to this test. Coefficient $n=0.0192$.

No. 145, Expt. H-33, Bitter Root Valley Irrigation Co., Montana. This test was made on a reach of canal following a contour, giving gentle curves joined by short tangents. The bottom is covered with sand and fine gravel with an occasional cobble of two-fist size. The reach is uniform in cross section, which probably accounts for a lower value of n than would be expected in this type of canal. Coefficient $n=0.0196$.

No. 149, Expt. S-57, lateral No. 7, Turlock Irrigation District, California. This canal was tested so late in the season that it was carrying but a small portion of its capacity. The reach is straight, in hard-packed smooth sand. The water being low, the grasses on the banks did not affect the flow at the time of the test (Pl. X, fig. 3). The slope is so gentle that a slight error in levels would appreciably affect the value of n . Coefficient $n=0.0202$.

No. 151, Expt. H-17, Billings Land & Irrigation Co., Montana. This reach of canal, located 400 feet below a tunnel and 200 feet above a flume, is in sidehill excavation of mixed earth and sand-rock with some shale. It was fairly clean, with some loose rock and sand deposits, while there is a slight growth of trailing moss at the lower end. Coefficient $n=0.0204$.

No. 155, Expt. H-34, Bitter Root Valley Irrigation Co., Montana. This test was made on a ditch in its fifth year of operation. The reach is straight, with bottom and sides covered with graded sand and gravel, to cobble size. The sand filling the interstices between larger pieces probably accounts for a value of n far below that of a cobble ditch. Coefficient $n=0.0208$.

No. 157, Expt. H-35, Bitter Root Valley Irrigation Co.'s Canal, Montana. This reach of canal, rather irregular in form, was excavated in hardpan. Drifting sand has smoothed over some of the irregularities. The alignment is as follows: Stations 0 to 3, small reverse curves; 3 to 7, tangent; 7 to 7+50, a 20° curve; 7+50 to 10, tangent. Coefficient $n=0.0211$.

No. 158, Expt. H-14, lateral No. 2, Billings Land & Irrigation Co., Montana. This test was made on a straight reach of ditch, originally excavated in sandy loam soil with some gravel. The present condition of the bottom is smooth, unshifting sand, evenly distributed. The writer is of the opinion that this test is quite comparable with No. 149 above. Coefficient $n=0.0212$.

No. 160, Expt. G-1, Morris Canal, Louisiana. This reach covers a straight section of a large rice-irrigation canal. The previous winter it had been plowed, leaving the bed rough. Water grasses retarded the velocity near the edges. The slope is very gentle, making an accurate determination thereof difficult. The value of n is lower than the writer would expect from the description. Coefficient $n=0.0216$.

No. 161, Expt. H-25, Hedge Canal, Montana. This test was made on a reach of canal excavated in soft granite sidehill. The present section is covered with disintegrated granite, mostly less than $\frac{1}{2}$ -inch size, but there are a few up to two-fist size. The general condition of alignment is brought out in Plate XI, figure 1. Coefficient $n=0.0216$.

No. 162, S-78, Birch Canal, Imperial Water Co. No. 1, California. This canal was originally excavated in alluvial silt soil, but deposits of sand on the bottom and growths of grass looking like half-grown oats have completely changed the nature of the channel. The water in this valley, from the Colorado River, is heavily charged with silt at all times of the year, and this forms a slick deposit which will withstand a high velocity before scouring. Prior to 1910 but little sand came down the canals, and the value of n was about 0.017 for canals free from growths, but during the past few years the energy required to transport more or less shifting sand has increased the value of n . The conditions and values in this test and No. 215 are directly comparable, the higher value of n in No. 215 being due to the denser growth of grass as shown in the views, Plate XI, figure 2. Coefficient $n=0.0217$.

No. 164, Expt. G-6, Crowley Canal, Louisiana. This test was made on a straight reach of rice canal. Before the beginning of the irrigation season the canal bed had been plowed and harrowed. Grass interfered with velocity near the sides. (See Pl. XII, fig. 1.) Coefficient $n=0.0219$.

No. 167, Expt. H-8, high line of Big Ditch, Montana. This test gives a good example of what may be expected in a ditch of this type. Originally constructed in a gravel soil, the low velocity has permitted the deposit of silt until the bed of the ditch is smoothed over and the value of n is much smaller than it was in the new ditch. This reach follows contours with sharp curves, joined by short tangents. Coefficient $n=0.0220$.

No. 172, Expt. S-64, Santa Ana and Orange main canal, California. This test shows the value of cleaning a ditch to increase the carrying capacity. The alignment (Pl. XII, fig. 2) follows a gently curving contour. The reach had been well shoveled out within a few days, removing all retarding influence from grasses and moss. There was a very little soft sand near the sides of the section with occasional pockets of sand. The value of n is comparable with that in No. 204, which is on the same kind of a canal subject to the same conditions but has not been cleaned recently. Coefficient $n=0.0221$.

No. 173, Expt. S-80, central main canal, California Development Co., California. This test was made on a long reach of straight canal. The banks were nearly vertical as left by cleaning of silt with a bucket dredge. The bottom is very hard and quite regular, despite this method of cleaning. The velocity was retarded for about 1 foot from each bank by a growth of tules. The silt-laden waters form slick banks. Plate XII, figure 3, shows the reach tested and the portable rating car in action. If freed from growth at all times, which is impracticable in this region, the value of n would be under 0.020. For small canals in this region see Nos. 162 and 215. Coefficient $n=0.0221$.

No. 174, Expt. H-20, Billings Land & Irrigation Co., Montana. This canal was originally constructed in varied strata having an earth surface underlaid with a stratum of gravel, while the bed of the canal was in Benton shale. This has now been covered in places with graded gravel. In general the upper end of the reach tested had a smaller sectional area, consequently a higher velocity, and the gravel was scoured clean, while the lower end of the reach had a lower velocity, and the gravel influence had been reduced by the deposit of silt. Coefficient $n=0.0221$.

No. 175, Expt. S-84, Salt River Valley Canal, Salt River project, United States Reclamation Service, Arizona. This test was made on a straight reach of canal originally constructed in graded gravel underlying silty loam soil. The high velocity encountered (mean 3.12 feet per second) scoured the bed of the canal, exposing hard-packed small gravel, while near the sides a slick deposit of silt formed a surface with but little retarding action on the water. The fringe of grass and small roots at the extreme edges (Pl. XIII, fig. 1), influenced but a very small portion of the flow. Coefficient $n=0.0222$.

No. 178, Expt. H-2, Big Ditch near Billings, Mont. This test was made on a canal originally excavated in Billings loam, which tends to be clayey. The bed of the canal is in the original earth with a slight deposit of sand which undercuts beneath the feet in wading, showing that the mean velocity, 2.09 feet per second, was almost sufficient to cause scouring of sand deposit. Fine mud has been deposited at the sides where the velocities are low. Coefficient $n=0.0225$.

No. 179, Expt. H-38, Bitter Root Valley Irrigation Co., Montana. The first half of this reach is on tangent, while the second half is on a 20° curve around a gravelly point. On the tangent the bed of the canal is covered with fine sand in serrations from 1 to 2 feet longitudinally with the canal and about 6 inches deep. In the second half of the reach the sand covers the middle portion of the bed, while gravel up to cobble size forms the edges. The value of n found, 0.0226, is lower than is to be expected on this type of channel.

No. 180, Expt. S-40, Lateral No. 10, Orland project, United States Reclamation Service, California. Many of the conditions holding for this test are clearly shown in Plate XIII, figure 2. The gravel, most of which is under hen's-egg size, is well compacted in the bed of the ditch, while a few scattered patches of moss have a retarding influence. There were about two patches, each 5 feet in diameter, in each 100 feet of length down the ditch. Coefficient $n=0.0228$.

No. 184, Expt. S-39, main canal, South Orland project, United States Reclamation Service, California. This reach of earth channel (Pl. IV, fig. 3) lies just above the lined section tested in No. 51. It is straight, originally constructed in a yellow clay which is very slick when wet. A darker deposit of silt now covers much of this clay. A value of n of about 0.017 might be expected but for patches of moss and water grasses occupying about 20 per cent of the bottom of the channel. This influence brings about a value of 0.0231 for n .

No. 186, Expt. S-36, River Branch Canal, Sacramento Valley Irrigation Co., California. This ditch was originally excavated in Sacramento silty clay loam, which breaks into very hard small clods (Pl. XIII, fig. 3). The bed of the ditch was very slick and hard. A few scattered soft lumps of mud and a fringe of grass retarded the

water and thorns extending out 1 foot raised the value of n from about 0.017 to 0.0236. Although the mean velocity is nearly 3 feet per second, there was no sign of scour in this hard soil. Coefficient $n=0.0236$.

No. 190, Expt. G-4, a small, new ditch in Louisiana. As shown in Plate XIV, figure 1, this ditch was practically as left by a plow, being but a week old. The reach is straight. Coefficient $n=0.0246$.

No. 192, Expt. S-88, Boulder and White Rock Ditch, Colorado. This reach tested on a small ditch with one bend (Pl. XIV, fig. 2). The original excavation was in meadow soil over river gravel. The bed contained graded gravel, mostly small-but with a few cobbles of two-fist size. A dark silt had deposited in the lower velocities near the edges which were quite vertical, well-sodded banks. This ditch would be called in a good working condition as most of the stones were unavoidable. Coefficient $n=0.0248$.

No. 193, Expt. H-3, Billings Land & Irrigation Co., Montana. This reach (Pl. XIV, fig. 3) was originally excavated in Billings gravel. Silt has deposited in the low velocities at the sides, but the main bed is composed of gravel with cobbles up to two-fist size. The slight fringe of grass did not retard the main flow. Coefficient $n=0.0258$.

No. 194, Expt. S-23, a lateral of the South Side Twin Falls Canal, in Twin Falls, Idaho. Excavation for this ditch was through about 1 foot of lava-ash soil before striking hardpan. The present bed of the lateral is clean and hard as soft rock. A dense growth of sod and long grass retards the water at the vertical sides, and some silt has deposited on the edges of the bottom in the low velocities. The reach tested is shown in Plate XV, figure 1. Coefficient $n=0.0259$.

No. 195, Expt. H-1, Billings Land & Irrigation Co., Montana. A straight reach of canal excavated in gravelly soil was tested. The bed of the canal is of compact gravel up to one-fist size, while silt has deposited in the lower velocities near the sides. There is no grass in the water section. The mean velocity of the water encountered, 2.35 feet per second, appears to be sufficient to prevent the deposit of silt over the bed, though the water is very muddy. Coefficient $n=0.0259$.

No. 197, Expt. H-36, Bitter Root Valley Irrigation Co., Montana. The first two-thirds of the reach tested lies on a sidehill in hardpan, while the last third, originally constructed on a creek bottom, is now formed of sand drifts similar to those spoken of in No. 179. In the first part the hardpan is scoured clean except on inside of curves where sand has deposited, while lower down the ditch some cobbles are mixed with the sand. Coefficient $n=0.0260$.

No. 198, Expt. S-14, North Ogden Canal, Utah. This reach of canal follows a hill-side contour about one-half mile below the mouth of Ogden Canyon. The material is composed of soil and rounded boulders ranging from sand to several hundred pounds in weight. The sides were quite vertical and fringed with willow roots and grass, while a few patches of moss were scattered throughout the length of the reach. Aside from this moss this test would come under the class of cobble-bottom ditches, and the value of n 0.0262 is about right for such ditches.

No. 199, Expt. S-56, Main Branch Canal, Turlock Irrigation District, California. When tested this canal was carrying but a small part of its total capacity (Pl. XV, fig. 2). The water was so low that the influence of grass, which would have affected a deeper section, was lost. The bed was formed of hard-packed fine sand. The gentle curve shown in the view occurred between stations 5 and 7. Coefficient $n=0.0262$.

No. 200, Expt. H-4, Billings Land & Irrigation Co., Montana. A straight reach excavated in graded gravel up to two-fist size underlying about 1 foot of soil. The canal is nine years old. Mud has deposited in the slower velocities at the sides. Dense grass fringes the edge but does not trail in the water. Coefficient $n=0.0264$.

No. 202, Expt. S-8, Salt Lake City and Jordan Canal, Utah. This test was made on a reach of canal with one gentle curve in the upper end, but otherwise straight. Originally constructed in sandy soil with small gravel, the bottom now is very hard and



FIG. 1.—SALT RIVER VALLEY CANAL, UNITED STATES RECLAMATION SERVICE,
ARIZONA.

(No. 175—Downstream from Station 5.)



FIG. 2.—LATERAL 10. ORLAND PROJECT, UNITED STATES RECLAMATION SERVICE,
CALIFORNIA.

(No. 180—Upstream from Station 5.)



FIG. 3.—RIVER BRANCH CANAL, SACRAMENTO VALLEY, CALIFORNIA.

(No. 186—Upstream from Station 6. Station 9 below first bridge in distance.)



FIG. 1.—SMALL NEW DITCH IN LOUISIANA. (No. 190.)



FIG. 2.—BOULDER AND WHITE ROCK DITCH, COLORADO.
(No. 192—Upstream from Station 2.)



FIG. 3.—BILLINGS LAND & IRRIGATION CO. CANAL, MONTANA.
(No. 193—Upstream from lower end of reach.)



FIG. 1.—LATERAL, SOUTH SIDE TWIN FALLS, IDAHO.
(No. 194—Downstream from Station 0.)



FIG. 2.—MAIN BRANCH, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.
(No. 199—Upstream from Station 8.)



FIG. 3.—FULLERTON DITCH, CALIFORNIA.
(No. 204—Upstream from Station 5.)



FIG. 1.—LATERAL 10. ARIZONA CANAL, UNITED STATES RECLAMATION SERVICE, ARIZONA.

(No. 213—Upstream from Meter Station 7.)



FIG. 2.—BEECH CANAL, IMPERIAL VALLEY, CALIFORNIA.

(No. 215—Upstream from Meter Station 10.)



FIG. 3.—LOWER CANAL, RIVERSIDE, CAL.

(No. 224—Upstream from Station 2.)

cemented except at the sides, where the velocity (mean 1.57 feet per second) is not sufficient to prevent silt from depositing. A dense growth of grass killed the velocity for about one-half foot from the banks, which were quite vertical and are typical of the old ditches in Colorado and Utah. Coefficient $n=0.0267$.

No. 204, Expt. S-66, Fullerton Ditch of the Anaheim-Union Water Co., California. Station 0 of the reach tested is at the lower end of a gentle curve (Pl. XV, fig. 3), while about 100 feet below station 6 there is an angle of about 80° to the right which checks up the water so that a correction for change in velocity head was necessary in computing the value of n . Grass and moss kill the velocity for about 1 foot from the banks, while the bed of the canal is a hard, cemented, sandy loam soil, with about 0.1 foot of shifting sand. This canal was under exactly the same conditions as No. 172, except that this needed cleaning and the other one had just been cleaned. The difference in value of n is about what should be expected and shows the value of cleaning. Coefficient $n=0.0269$.

No. 205, Expt. S-86, Farmers' Canal, near Boulder, Colo. When tested this ditch was carrying about half its capacity. It is constructed along a gently curving hillside. Willows and grass form a dense fringe at the sides, while the bottom, originally constructed in red mountain soil mixed with fragments of sandstone, now has a rather hard, gravelly bottom, with angular fragments rather than rounded pebbles. The section is irregular, and the value of n is quite comparable with that of a cobble-bottom ditch, although this reach is not cobble bottomed. Coefficient $n=0.0270$.

Nos. 206, 207, and 208, Expts. H-12 a, b, and c, lateral 2, Billings Land & Irrigation Co., Montana. These tests are on an irregular section of small lateral, constructed in loamy earth. It is now fringed with grass, which trails somewhat, though newly mowed. The discharge was varied for the various tests. The bottom is irregular, with drifting sand throughout most of the reach. The canal is too irregular to concede too much weight to the various values of n found.

No. 209, Expt. S-60, Yosemite Power Co.'s Ditch. This ditch follows a mountain contour in disintegrated-rock soil. A fringe of bushes and grass retard velocity at the banks, while the bottom is porous and gravelly with scattered boulders and rock fragments up to two-foot size. The value of n is about what may be expected of a cobble-bottom ditch, although this one does not strictly class as such. Coefficient $n=0.0274$.

No. 210, Expt. S-5, lateral of Parley's Ditch, Utah. This test is on a straight reach in gravelly loam soil. A fringe of grass retards velocity for about one-half foot from the banks. The bottom is composed of clean sand which yields about 0.1 foot to the feet, in wading. A slight wind upstream makes the value of n a little high. Discounting the wind, this value would be about that of test No. 209 above. Coefficient $n=0.0278$.

No. 212, Expt. S-20, lateral of South Side Twin Falls Canal, Idaho. This reach of ditch is on a gentle contour curve of about 400 feet radius. Constructed in hardpan underlying about a foot of lava-ash soil, the water section is quite slick but is badly washed in longitudinal gullies. The banks, too, are irregular and fringed with a dense growth of grass and alfalfa. Coefficient $n=0.0283$.

No. 213, Expt. S-85, lateral 10 from Arizona Canal, Salt River project, United States Reclamation Service, Arizona. This test is on a straight reach of small ditch on a steep grade. Constructed in a silt loam soil, the high velocity has washed very irregular gullies and pockets. An average growth of grass and weeds also retards velocity. (See Pl. XVI, fig. 1.) Coefficient $n=0.0284$.

No. 215, Expt. S-79, Beech Canal, Imperial Water Co. No. 1, California. This test is under exactly the same conditions as those described in No. 162, with the exception that a longer time has elapsed since the dense growth of grass shown on Plate XVI, figure 2 was cut. The difference in grass condition is noted by comparing the above view with that in Plate XI, figure 2. Coefficient $n=0.0290$.

No. 216, Expt. S-49, Wheeler Ditch, Nevada. This test was made on a ditch following a contour in curves of from 300 to 500 feet radius. While the bottom is hard many boulders of several hundred pounds weight border the channel, and a few have rolled into it. A dense growth of grass and bushes fringe the sides, and a fine, dense moss retards velocity for about 0.3 foot from the bottom. Coefficient $n=0.0292$.

Nos. 219 and 220, Expts. H-13c, lateral of Billings Land & Irrigation Co., Montana. These tests were made on the same reach of canal but with varying discharges, and for No. 219 grass fringing the edges was cut, hence removing some of the retarding influence present in No. 220. The bottom is covered with fine, deep, shifting sand, so "quick" that a wading man sinks about 1 foot.

No. 221, Expt. S-59, main canal, Modesto Irrigation District, California. This test was made on a wide canal with but a small portion of its total capacity running. This gave a condition of shallow water flowing over gullied hardpan having about 0.1 feet of shifting sand. No grass touched the water at this stage. Coefficient $n=0.0300$.

No. 222, Expt. S-72, Upper Canal, Riverside Water Co., California. This test was on a straight reach of canal originally excavated in a sandy loam soil. At present the bottom is covered with a bed of fine sand which remains quite hard until disturbed, when it cuts rapidly. Dense grass along the sides and scattered patches of moss in the canal cause a high value of n . Coefficient $n=0.0315$.

No. 223, Expt. S-77a, Lower Canal, Riverside Water Co., California. Though originally excavated in a clean-cut section of soft hardpan, the present condition of this reach is much less efficient, due to a deposit of shifting sand and growths of water grasses and dense grass along the edge, though not so bad as in No. 224 below. Coefficient $n=0.0318$.

No. 224, Expt. S-77b. Same canal as No. 223 above, but the grass along the edge kills velocity for about 1 foot from both banks. Otherwise the same general condition holds as before. This reach adjoins the other reach at a right-angled bend shown in Plate XVI, figure 3. Coefficient $n=0.0360$.

No. 228, Expt. S-9, Lower Canal from Big Cottonwood Creek, Utah. This test was made on a ditch which would have an efficient carrying capacity with a small amount of labor, but through neglect willow roots and grass have so encroached on the channel that a high value of n is obtained. Originally constructed in a sandy loam soil, the bottom was quite hard with no cobbles but with a deposit of soft mud in the lower velocities near the sides. The reach tested is on a gentle contour curve, which exerts an inappreciable influence when compared with the vegetable growth. The banks are quite vertical and irregular, like most rooted channels. Coefficient $n=0.0324$.

No. 230, Expt. S-62, Golden Rock Ditch, Yosemite Power Co., California. This reach tested follows a gentle mountain contour. The bottom is of clean disintegrated slate with scattered pieces to two-fist size. Although this bottom has a great retarding influence, the value of n is higher than is to be expected. There was but little grass touching the water. Coefficient $n=0.0346$.

No. 231, Expt. H-15, lateral 1, Billings Land & Irrigation Co., Montana. This reach of ditch is in sandy loam fill. The water section is irregular with sand in the bottom and a little trailing grass and moss. Coefficient $n=0.0349$.

No. 233, Expt. S-18, Logan and Hyde Park Canal in Logan, Utah. This straight reach of canal (Pl. XVII, fig. 1) was originally constructed in gravelly soil with many cobbles from egg to two-fist size. At the time of the test the edges were irregular and densely grassed, with patches of moss and some cobbles scattered throughout the reach. The moss lies usually within 0.3 foot of the bottom. Coefficient $n=0.0364$.

No. 235, Expt. S-53, lateral 2½, Turlock Irrigation District, California. This test is a straight reach of canal excavated in hardpan requiring blasting. This leaves the section rough and pitted. The bottom was covered with about 3 inches of rough,

gritty sand. As the canal was only about one-half full, no grass touched the water at the time of the test. Coefficient $n=0.0373$.

No. 236, Expt. S-42, Cochrane Ditch, Nevada. This ditch is constructed in gravelly soil with many cobbles. The test was made on a reach having one bend (see Pl. XVII, fig. 2). The bottom had many loose cobbles scattered on an otherwise hard gravel bed. The banks throughout nearly all of the reach tested were overhung with densely grassed sod. In addition about 20 per cent of the water section was occupied with moss. Coefficient $n=0.0379$.

No. 237, Expt. S-25, Perrault Canal, Capital Water Co., Boise, Idaho. This ditch (Pl. XVII, fig. 3) constructed in gravelly loam soil, has a very hard cemented bottom. A dense growth of grass so kills the velocity for a distance of about 1 foot from each bank that the value of n is very much greater than would be the case if the canal were kept free from this growth. Coefficient $n=0.0381$.

No. 239, Expt. S-46, Orr Ditch, in Reno, Nev. The reach tested passed in a horse-shoe curve around the small lake on the university campus. It was originally excavated in loamy soil with a little gravel. At time of test the bed was clean scoured, but near the sides a man wading sank about 4 inches in soft mud. Dense grass and willows retard the velocity at both banks, while the water section is very irregular throughout the reach. Coefficient $n=0.0397$.

No. 240, Expt. S-21, a small ditch in Twin Falls, Idaho. This is a small ditch with grass arching across in many places. Originally constructed in hardpan, the reach is irregular with scattered debris such as is so often found in town ditches. Coefficient $n=0.0399$.

No. 241, Expt. S-52, Capurro Ditch near Reno, Nev. As shown on Plate XVIII, figure 1, this is a small ditch thickly fringed with grass and with scattered cobbles in the bottom. The banks are quite vertical, densely rooted, and very irregular. The bottom is covered with about 0.1 foot of soft mud through which the scattered cobbles project. Coefficient $n=0.0403$.

No. 243, Expt. S-4, New Rutner Ditch, Nebraska. This ditch follows a gentle contour line down a creek bottom. At time of test the ditch had a very hard bottom of medium-fine gravel, well packed, but a dense growth of grass killed the velocity for about one-half foot from each bank, and scattered patches of moss retarded that in the middle. The banks of the ditch are very irregular. Coefficient $n=0.0436$.

No. 244, Expt. S-44, Sullivan and Kelly Ditch, Nevada. This test was made on a ditch excavated in a gravel and cobble hillside. At time of test the bottom was hard-packed gravel in the center with a slight deposit of soft mud at the sides. Scattered cobbles and a dense growth of grass retarded the velocity of the water. The reach follows a gently curving contour line with one right-angled bend near the lower end of the reach tested. Coefficient $n=0.0436$.

No. 245, Expt. G-2, Roller Canal, Louisiana. This test was made on a straight reach of canal. The vegetation shown in Plate XVIII, figure 2, extended for about 5 feet from each shore. Coefficient $n=0.0461$.

No. 249, Expt. G-5, a small ditch in Louisiana. This ditch was chosen as representative of the small ditches in the rice country. Grass extended from one bank to the other across the bed of the ditch, occasionally growing to the water surface from the bottom of the ditch. The grass forms a dense mat in the bottom. The grass had been cut with a scythe about one week before the test. Coefficient $n=0.0544$.

COBBLE-BOTTOM DITCHES.

No. 251, Expt. H-31, Bitter Root Valley Irrigation Co.'s Canal, Montana. This test was made on a nearly straight reach 600 feet long, excavated in very gravelly ground with bowlders up to 2 cubic feet in size. The first third of the distance fairly smooth on the bottom with no stones larger than two-fist size; upper slope cobbly and with

some grass on the lower water edge. Second third of distance much roughness, with cobbles over most of bottom. Last third, in condition intermediate first and second thirds. Coefficient $n=0.0262$.

No. 252, Expt. S-10, Upper Canal from Big Cottonwood Creek, Utah. This reach of canal follows a gentle contour curve on a very gravelly hillside. The sides are nearly vertical and lined with trees and willows whose rootlets extend into the water prism. The bottom is completely covered with cobbles up to two-fist size. Like nearly all ditches of this character the sides are irregular in outline, as the cobbles do not break into an even bank. Coefficient $n=0.0277$.

No. 253, Expt. S-15, Logan and Northern Canal, Utah. This is a fine example of a ditch following a gravelly hillside contour near the mouth of a canyon, a condition typical of many canals near the mountains. The sides are densely fringed with willows and bushes whose rootlets hold silt and form nearly vertical banks. The bottom is completely covered with well-packed gravel and cobbles up to two-fist size. Coefficient $n=0.0270$.

No. 254, Expt. S-51, Reno Ditch of the Reno Light & Power Co., Nevada. This reach of canal was originally excavated in an old river bed containing innumerable bowlders up to 5 cubic feet in size (Pl. XVIII, fig. 3). About a year before this test the sides and bottom of this channel had been paved with a hand-laid riprap of these bowlders, the sides being laid about $\frac{1}{2}$ to 1, and the bottom flat. Many of the bowlders at the top of the walls have rolled into the canal, as no cement or other bond was used, but the general condition of the walls appears to be good. The reach tested was straight with the exception of a gentle curve in the last 200 feet. Coefficient $n=0.0291$.

No. 255, Expt. S-43, Sullivan and Kelly Ditch, Nevada. This reach follows a gentle contour on a rocky hillside (Pl. XIX, fig. 1). The bowlders have been hand laid in a nearly vertical wall on the lower side while the bottom and upper side are rough and irregular with projecting large bowlders. A slime of mud from the Truckee River water covers all rocks below the water line. Vegetation is negligible. Coefficient $n=0.0324$.

No. 259, Expt. S-89, Beasley Ditch, Colorado. This canal on a straight reach with a curve about 100 feet below the lower end. At the time of test it was carrying but about one-fourth its capacity. The bottom and sides are a mass of unpacked gravel and bowlders up to 2 cubic feet in size. Coefficient $n=0.0383$.

SIDEHILL CUTS, WITH RETAINING WALLS.

No. 261, Expt. H-23, Hedge Canal, Montana. This test was made on a short reach excavated in granite hillside, with the lower bank formed of a random rubble masonry wall, well plastered with mortar on the nearly vertical water face. The reach is straight except for a slight curve in the last 50 feet. The bottom is covered with granite gravel, most of which would pass a $\frac{1}{2}$ -inch screen, with occasional pieces one-fist size. The excavation is quite true to line for a rock cut. Coefficient $n=0.0185$.

No. 262, Expt. H-27, Hedge Canal, Montana. This reach is about 500 feet below that in No. 261. The upper side is excavated quite true to line in earth and disintegrated granite. The lower side is a vertical concrete wall laid against board forms. The floor is concrete with from 1 to 2 inches of fine, sharp ravelings from the hillside. In scattered spots the floor shows. The reach is 450 feet long. Station 1 to 2 is about a 20° curve, on 12-foot chords. At station 3+40 is a rather sharp bend. The rest is fairly straight. Coefficient $n=0.0225$.

No. 263, Expt. H-9, Cove Ditch, Montana. This reach is cut from a sandstone hillside (Pl. XIX, fig. 2). The lower bank is a rubble masonry wall plastered with concrete on the water side. The bottom is also overlaid with concrete. The alignment is wavy with some 20° curves. From stations 0 to 2 there is some gravel; from stations 2 to 4, clean bottom, the rock on upper bank being smooth but the width



FIG. 1.—LOGAN AND HYDEPARK CANAL, UTAH.
(No. 233—Upstream from Station 2.)



FIG. 2.—COCHRANE DITCH, RENO, NEV.
(No. 236—Upstream from Station 5.)



FIG. 3.—PERRAULT CANAL, BOISE, IDAHO.
(No. 227—Downstream from Station 0.)



FIG. 1.—CAPURRO DITCH, NEVADA.
(No. 241—Downstream from Station 1.)



FIG. 2.—ROLLER CANAL, LOUISIANA.
(No. 245—Showing meter station.)



FIG. 3.—RENO DITCH, NEVADA.
(No. 254—Downstream from Station 0.)



FIG. 1.—SULLIVAN AND KELLY DITCH, NEVADA.

(No. 255—Downstream from Station 1.)



FIG. 2.—COVE DITCH, MONTANA. (No. 263.)



FIG. 1.—LOGAN, HYDEPARK, AND SMITHFIELD CANAL, UTAH.
(No. 264—Downstream near lower end of reach.)



FIG. 2.—LOWER CANAL, RIVERSIDE, CAL.
Note plank lining. (No. 268—Upstream from Station 6.)



FIG. 3.—LOGAN, HYDEPARK, AND SMITHFIELD CANAL, UTAH.
(No. 269—Downstream past meter station.)

irregular; from stations 4 to 6, more uniform in width but rough on rock side; from stations 6 to 7, rock wall is rough and width variable; from stations 7 to 8, rock wall quite smooth, bottom clean or little gravel, the width uniform. Coefficient $n=0.0228$.

No. 264, Expt. S-17a, Logan, Hyde Park and Smithfield Canal, Utah. This test made on a reach 337 feet long between an earth section and the reach in No. 266 below (Pl. XX, fig. 1). The excavation is on a steep hillside. The upper bank is mostly of willow roots, while the lower bank is a well-made concrete wall. The bottom is covered with coarse gravel. This reach is nearly straight with bends at both ends. This is classed as B rating by reason of these bends. Coefficient $n=0.0256$.

No. 265, Expt. H-26, Hedge Canal, Montana. This reach is excavated in rock cut with concrete floor and a rubble masonry lower wall, faced with 3 inches of concrete, deposited against wood forms. The bottom is mostly covered with sand and ravelings of small rock. The upper bank is rough rock excavated quite true to cross section. The alignment is practically straight except for one sharp curve between stations 0+80 and 1+50. The value of n is higher than in No. 262, which has a smoother section. Coefficient $n=0.0269$.

No. 266, Expt. S-17b, Logan, Hyde Park and Smithfield Canal, Utah. Just below the reach described in No. 264 the canal enters the section covered in this test. The same concrete wall formed the lower bank, and the bottom was about the same, but the upper bank is a rough vertical rock cut. The difference in the value of n is about what is to be expected. Coefficient $n=0.0278$.

MISCELLANEOUS SECTIONS.

Nos. 267 and 268, Expts. S-74 and S-73, lower canal, Riverside Water Co., California. These tests made on a straight reach of canal in a sandy soil with a shifting sand bottom and a wood lining on the lower side (Pl. XX, fig. 2). The canal in test No. 267 is in the shade of a dense row of trees and is free from moss accumulations. Coefficient $n=0.0249$.

The canal in test No. 268 is in the sun and moss has accumulated on the wood lining. Coefficient $n=0.0291$.

In both tests the water was retarded by a rank growth of grass for about 1 foot from the bank opposite the wood lining. The difference in the values of n is directly due to the moss which grows in sunlight and does not in shade.

No. 269, Expt. S-17c, Logan, Hyde Park and Smithfield Canal, Utah. This reach is fairly straight, excavated in rough rock. The bottom is strewn with coarse gravel (Pl. XX, fig. 3). Coefficient $n=0.0298$.

THE USE OF VALUES OF n .

The engineer is required to exercise his judgment as to the value of n in two general ways:

1. The value to be substituted in the formula in the design of a channel or in the changing of a channel from one containing material to another.

2. The value that is to be used when the engineer is called upon to determine the maximum carrying capacity of a canal already constructed but at the time of inspection carrying no water or but a small portion of its capacity.

In the design of channels it has been customary to allow little or no factor of safety. In the opinion of the writer it is as necessary to allow for a slight overload in a canal as in any other conservative construction. This should be accomplished by choosing as nearly

as possible the correct value of n and then designing for whatever overload is deemed conservative. Another method which is sometimes followed is to choose a relatively high value of n and then design for the desired discharge. This method is not to be recommended and in some cases may be even dangerous for the reason that the velocity may so increase beyond a safe figure for the containing material that the canal can be eventually operated at but a part of its designed capacity. This fact is brought out in the case of a prominent canal in western Nebraska. A value of n of 0.025 was chosen as applying to such a canal in a moderate state of operative efficiency. As determined by numerous experiments, the material cemented into a smooth, hard canal bed with an efficiency almost equal to concrete; that is, n is actually about 0.016, and when operated to about one-half its depth the velocity becomes so high that there is great danger of scouring the channel. Thus a large portion of the excavated area of the canal can not be used unless lined with some material which would withstand scouring or else checks installed to reduce the grade. Had the correct value of n been chosen at the time of construction, the slope might have been far less than it is and additional territory made irrigable or a different-shaped cross section might have been chosen which would have had about the same yardage per given length and the same ultimate carrying capacity as was desired for the present canal.

In the second case cited above, where the engineer must estimate the carrying capacity of a canal already constructed, there is room for divergence in the estimates of two men equally competent and using data collected under the same conditions.

If the canal is carrying its capacity at the time of inspection the results of two men should agree quite closely, as it is a mere matter of making a discharge measurement.

If the canal is about half full a careful measurement may be made similar to the ones for the experiments described in this publication. From this experiment the value of n holding for the given condition may be determined. If the canal is straight and there is no influence from structures it may be safely assumed that the surface slope will remain quite constant up to capacity. Any material change in the value of n must be determined by the influence of the two banks above the surface of the water flowing at the time of test. A clean concrete, wood, or steel channel will have a slightly lower value of n . An earth channel rarely has the same character of material throughout the length of the wetted perimeter, and due allowance must be made for changes.

This involves the judgment of the engineer, and two men will disagree more or less at this point. The general elevation of where the water surface will be when the canal is full is another place where the

estimates of two men will separate. The lines of levels run by the two may develop slightly different critical points in the canal bank at which the canal would overflow. The depth of freeboard between the capacity water surface and the lower bank profile will probably differ. The controlling cross sections will not necessarily agree.

If the canal is dry at the time of inspection, then the solution of the problem as to the capacity is further complicated by the fact that no test can be made to determine the value of n , and the judgment alone must be relied on as to the correct value. The surface slope is also indeterminate, and a grade line through the controlling points of the profile of the canal bed must be assumed as the slope. This value also will be different in two estimates.

In the courts of law of the Western States many attorneys and judges have come to regard as the last word a statement to the effect that the capacity of a canal has been computed by Kutter's formula. While the algebra of the formula is an exact science and exactly the same answer will be obtained by several parties if the same hydraulic data, including the value of n , are assumed, the fact remains that the assumption of the value of n may be largely a matter of judgment, and the results of two men should not be discredited merely for the reason that they disagree slightly.

RECOMMENDATIONS FOR VALUES OF n FOR DIFFERENT KINDS OF CHANNELS.

Either in the design of canals or the determination of the carrying capacity the material forming the perimeter divides into the following general classes: 1, concrete lining; 2, wooden flumes; 3, metal flumes; 4, masonry lining; 5, earth canals; 6, cobble-bottom canals; and 7, sidehill cuts with retaining walls. There are a few special cases that do not come under any one of the classes mentioned, but a proper comparison can be made by assuming parallel conditions.

The following values are applicable for velocities up to about 5 feet per second and with hydraulic radii up to about 2 feet. If velocities and radii are greatly to exceed the above figures, slightly lower values of n should be used.

VALUES OF n FOR CONCRETE LINING.

I. $n=0.012$ for the highest grade of material and workmanship and exceptionnly good conditions. The surface of the lining to be as smooth to the hand as a troweled sidewalk. The expansion joints to be so well covered that they practically fulfill the same condition. The climate and water to be such that moss does not accumulate to any great extent. The water to be practically free from shifting material. The alignment to be composed of long tangents joined by spiraled curves, while the interior of the channel must be of uniform dimensions, true to grade throughout the cross section.

II. $n=0.013$ for construction as in type I, but with curves as in the usual mountain canyon. Same construction and alignment as in type I, but with small amount of sand or débris in water. Construction as in type III, but in very favorable alignment or for water that carries a small amount of fine silt that will eventually form a slick coat.

III. $n=0.014$ for linings made by good construction under favorable conditions. The surface to be as left by smooth-jointed forms or to be roughly troweled. Joints to be good, but causing some retardation. Alignment about equal in curves and tangents, with no spirals between. The bed to be clean and sides free from rough deposits. In the opinion of the writer this is the value to use for most linings on moderate-sized channels.

IV. $n=0.015$ for construction as in type III, but with sharp curves and clean bottom or moderate curves and much débris on the bottom but clean-cut sides.

V. $n=0.016$ for concrete as constructed by the average gang of laborers, using forms that leave prominent lines at the cracks, no finish coat being applied. Bed to have the usual small amount of rock fragments and patches of sand and gravel. Average amount of curvature. In climates where a rough deposit accumulates, as in southern California, a lining that originally had a value of n about 0.013 quickly assumes about this type. For this reason it appears to the writer that labor and money spent in securing a very smooth surface is lost where the deposit accumulates on smooth or rough alike.

VI. $n=0.017$ for roughly coated linings with uneven joints. This value also is applicable where rough deposits accumulate on the sides and conditions of alignment are poor.

VII. $n=0.018$ for very rough concrete with sharp curves and deposits of gravel and moss. A broken gradient, irregular cross section, and the like, contribute to such a high value of n .

Where experiments show higher values of n than are given above for concrete linings, the conditions are such, as a rule, that the containing material has lost its identity as concrete or cement, and thick coatings of sand, accumulations of moss, or deposits of sand change the general classification of the channel.

VALUE OF n FOR WOODEN FLUMES.

While experimental flumes have been constructed that showed values of n in the neighborhood of 0.009, yet in making tests on flumes in commercial service values of n below 0.012 are so rare that it is not thought advisable to recommend any value less than this. Wood is subject to so many changes, due to the influences of climate, wind, settling of earth, moss accumulations, warping, and so on, that even when well constructed the value of n becomes greater after a

few months' use than when new, and it is better to use a value of n that will hold for the greater part of the life of the flume.

The above statements apply to the ordinary plank flume. Where staves are used which is quite rare since the advent of the steel flume, a lower value will probably hold throughout the life of the flume, for its very construction is such that it must stay in quite good condition or fail, due to the compression existing between the edges of the staves. In many cases the designer of a flume considers only the lumber, battens, and calking, while in actual practice the good influences of well-chosen materials are often completely lost through the accumulation of rock fragments, gravel, and so on. A very common location for a flume is down a bench cut in a rocky hillside. Whenever the cut is such that the fragments sloughing from the hill would fall into the flume, care should be exercised to keep the flume out from the side of the cut, or a guard wall should be constructed to divert débris so it will fall back of the flume. If high velocities are constantly to be maintained, ordinary dirt and small stones will roll on down the flume or accumulate on the inside of sharp curves. Short flumes are quite liable to take about the same value of n as the earth section above, as the same bottom becomes characteristic of both.

I. $n=0.012$ for well-constructed, clean flumes with surfaced lumber for both siding and battens. All lumber to run longitudinally. Alignment to consist of long tangents with gentle curves between. Construction to be such that the grade line will remain uniform, preventing sags and wavy alignment. A flume without battens may have a very slightly lower value of n , but this difference will be inappreciable if the added length of the wetted perimeter due to the battens is considered in the design. Some very smooth grades of roofing materials used as linings also give a slightly lower value of n , but not enough to consider. If flumes are calked with oakum or other stuffing, care must be used that none projects into the water section if a high degree of efficiency is to be maintained.

II. $n=0.013$ for well-constructed, clean flumes of surfaced lumber and battens, following mountain contours, where the alignment will consist of about equal gentle curves and tangents. This value will also apply to flumes with alignment and grade as described in type I, but with vertical battens at intervals, with projecting calking or a slight amount of hardened asphalt or other waterproofing retarding the velocity.

III. $n=0.014$ for flumes of very smooth interior, but with many bends or sharp curves. This value also applies to those of type I with a location such that a slight amount of hillside débris is unavoidable. Construction of type I, but with cracks poured with any water-

proofing material that hardens in tapering drops, is also liable to come in this type. For type I except that unsurfaced lumber is used.

IV. $n=0.015$ for flumes of unplanned lumber, but otherwise as of type II. In the opinion of the writer this is about the value to use for the usual grade of construction in a mountain canyon where the flume will get about the usual grade of maintenance with repairs made with irregular-shaped scraps of boards.

V. $n=0.016$ for flumes of type IV where sharp bends rather than curves are installed. For flumes lined with rough roofing material and for the ordinary grade of construction on a flume that is built and generally left to care for itself. The kind of an organization that is to operate the flume will determine this factor.

For values of n higher than 0.016 the inside of a flume has changed so that its character as a wooden flume is practically lost. Débris accumulations, warped and loose battens, excessive sagging, with consequent accumulation of débris, all contribute to make values above 0.016 rather indeterminate, except by actual test.

VALUES OF n FOR METAL FLUMES.

As noted in a bulletin of the Colorado Agricultural Experiment Station,¹ metal flumes are divided into three clean-cut groups.

Group 1. Those having countersunk joints between the various sheets of metal so that there is practically no added roughness presented to the water.

Group 2. Those having joints that project into the water section presenting a shoulder every few feet that effectually retards the velocity. This type is not installed to any great extent at present, but there is a great deal of it in actual use, as it was the pioneer in steel fluming.

Group 3. Those having regular corrugations at right angles to the axis of the flume. This makes a stiff flume, not so liable to sag, but with a rather high value of n .

I. $n=0.011$ for flumes of group 1, in favorable alignment and clean.

II. $n=0.015$ for flumes of group 2, in favorable alignment and clean.

III. $n=0.022$ for flumes of group 3, in favorable alignment and clean.

This value is based on but one observation, by Mr. Cone.

Where flumes are short, they are liable to accumulate the same class of detritus in the bottom as the section above them. Where the possibility of débris accumulations exists it should be considered in design.

¹ Colorado Sta. Bul. 194.

VALUES FOR n IN MASONRY-LINED CHANNELS.

The writer has not sufficient tests on masonry-lined sections to make suggestions as to specific values of n to use, but the following general observations seem to be warranted:

As a rule the proportion of the wetted perimeter extending across the bottom far exceeds that on the two sides; therefore the preponderance of influence comes from the bottom. If this be of smooth concrete and the sides are reasonably smooth, then the value of n approximating that in average concrete may be used. If the sides are unchinked, they will be rougher than the sides of the average earth canal, but again the bottom must be given the most weight.

VALUES OF n FOR EARTH CHANNELS.

The value of n in earth channels extends over a far greater range than in any other material. More complex conditions, more permutations and combinations of conditions exist than are possible in a channel that reasonable velocities can not erode. If kept clean, concrete, wood, or steel must maintain about the same cross section; as a rule, uniform. Earth, on the other hand, may form a definite boundary of a channel when new, but after a few years of operation the character of the boundary has entirely changed. Grass, weeds, and fibrous roots may form the material for nearly vertical sides, while the bottom may silt up or scour deeper, be smooth, or deeply pocketed. A distinct trapezoidal form changes to a segment of an ellipse, silt depositing in the lower corners, while the middle of the bed remains about the same or becomes strewn with rocks or gravel.

The values of n given in the following list cover the standard conditions, while a study of the descriptions of the channels under the earth-channel headings will disclose the influence that changes the value of n from one of these standards.

I. $n=0.016$ for excellent conditions of earth channels. The velocity to be so low that a slick deposit of silt may accumulate, or the natural material be such as to become smooth when wet. The influence of vegetation at the edges to be a minimum. The water to be free from moss and other aquatic growth. The alignment to be free from bends and sharp curves.

II. $n=0.020$ for well-constructed canals in firm earth or fine, packed gravel where velocities are such that silt may fill the interstices in the gravel. The banks to be clean-cut and free from disturbing vegetation. The alignment to be reasonably straight.

III. $n=0.0225$, although carried to one more significant figure, is given for the reason that it has long been used for this type and the tests do not disclose any reason for changing. This value for the average well-constructed canal in material which will eventually

have a medium-smooth bottom, with graded gravel, grass on the edges and average alignment or silt at both sides of the bed and scattered stones in the middle, or a smooth bottom with an average amount of grass and roots forming the sides. Hardpan in good condition, clay and lava-ash soil takes about this value.

IV. $n=0.025$ for canals where the retarding influence of moss, growths of dense grass near the edges, or scattered cobbles begins to show. The value of n in earth channels where the maintenance is neglected commences at this value and rapidly goes up. This is a good value to use in the design of small head ditches or a small ditch to serve but one or two farms.

V. $n=0.030$ for canals subject to heavy growths of moss or other aquatic plants. Banks irregular or overhanging with dense rootlets. Bottom covered with large fragments of rock, or bed badly pitted by erosion. Values of n between 0.025 and 0.030 also cover the condition where the velocity is so high that cobbles are kept clean and unpacked in the center of the canal, but silt deposits near the sides. For values above 0.030 the channel is much choked with vegetation, very irregular, crooked, overhung with dragging trees and grasses, or there is some other condition that should not be allowed to exist in a well-kept system.

VALUES OF n FOR COBBLE-BOTTOM CANALS.

The typical clean-washed cobblestone ditch is very common near the mouths of canyons. Where the cobbles are graded in size and well packed the value of n is about 0.027, but the value rapidly increases as the larger rocks predominate and the lack of graded sizes prevents packing.

ESTIMATION CHARTS.

As an aid to the designer of irrigation channels the writer has prepared two sets of curve charts.

The first set shows values of width and depth of channel as related to area and hydraulic radius. These elements for rectangular channels are shown in figure 4 and for trapezoidal channels having side slopes of $1\frac{1}{2}$ to 1 in figure 5. These cover the two shapes most commonly used, while the engineer working in materials that require other slopes may build up his own charts on the principle used in plotting figures 4 and 5.

The second set shows related values of velocity, slope, the friction factor n , and the hydraulic radius. This set is divided into three general classes. First. For construction in concrete, wood, or steel for ordinary slopes (fig. 6). Second. For the same materials of construction on very steep slopes (fig. 7). The latter chart is for use in the design of chute drops and covers slopes from 0.005 where figure

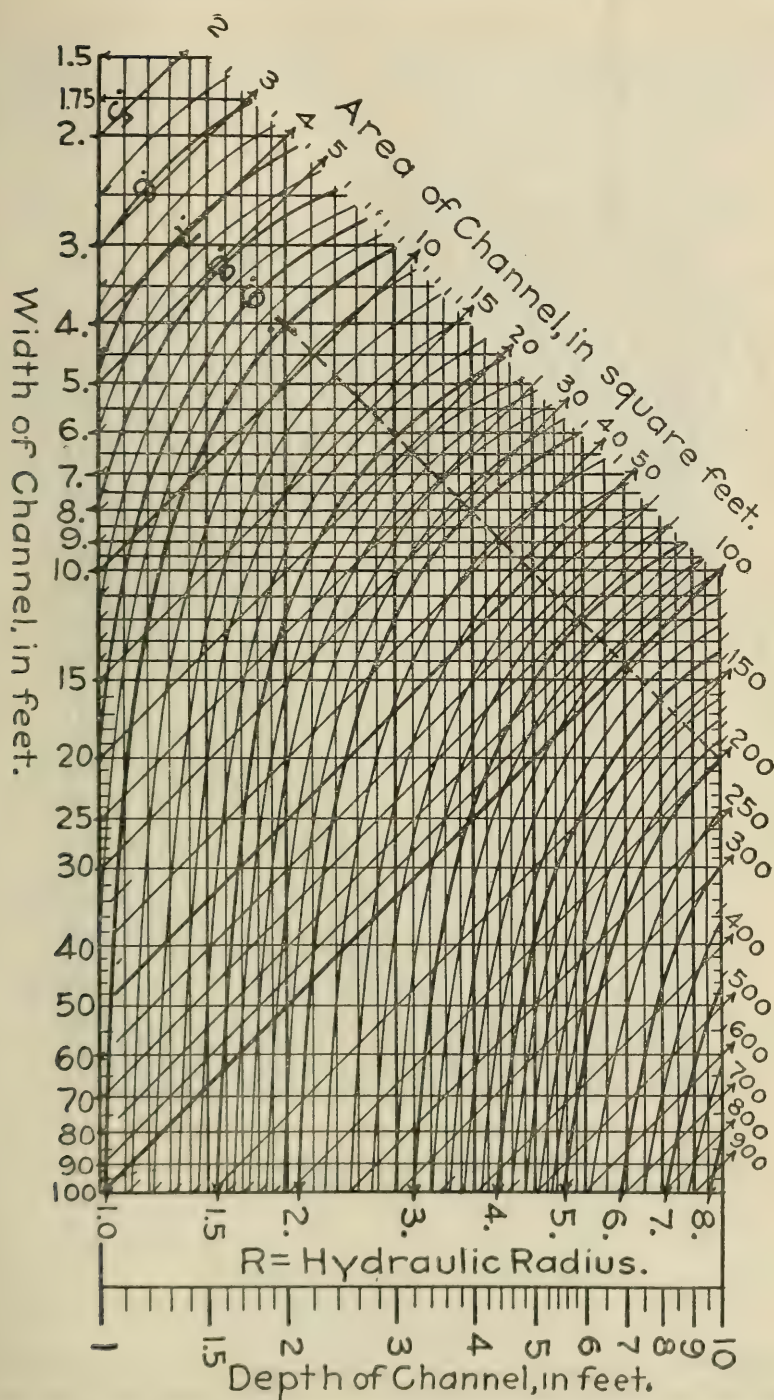


FIG. 4.—Areas, in square feet; hydraulic radii, in feet and hydraulic economic dimensions (broken line) for rectangular channels.

6 stops, up to 0.3, or 30 feet per hundred. Third. For very rough materials, for earth channels and for cobble-bottom ditches (fig. 8). The values of n range from 0.015 to 0.030 while the slopes cover all ranges likely to be encountered. On this chart the values of n cover

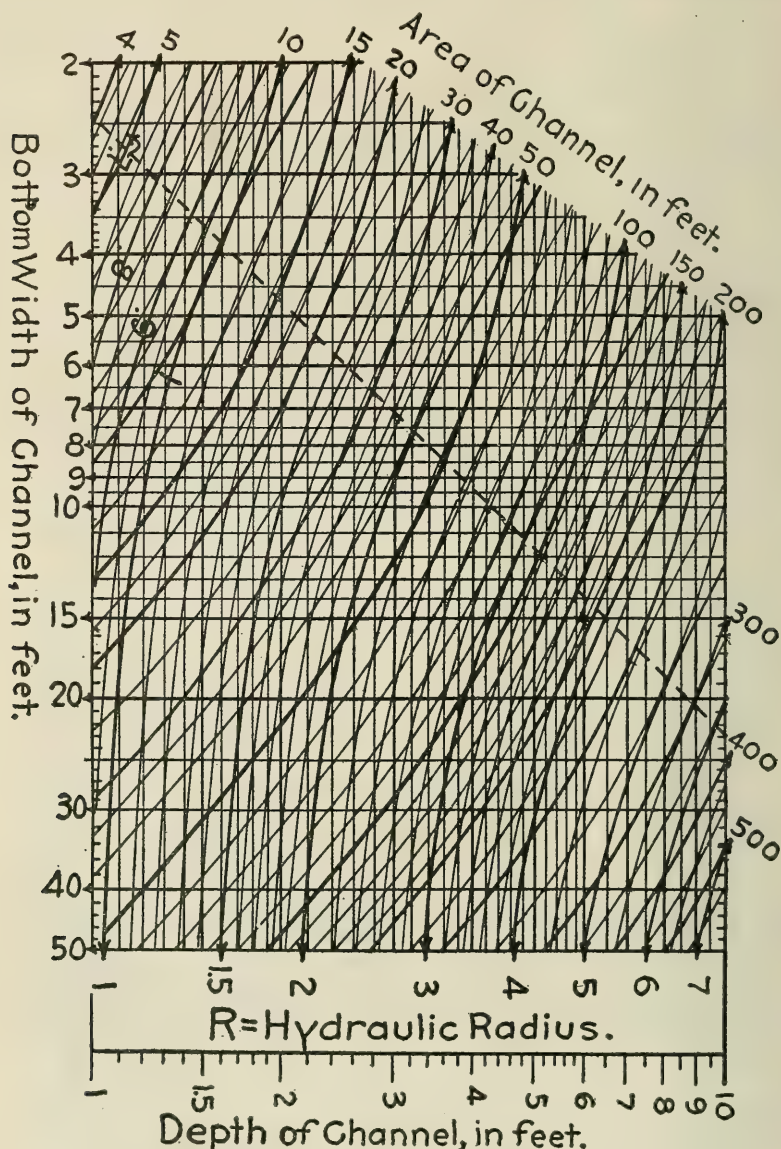


FIG. 5.—Areas, in square feet; hydraulic radii, in feet and hydraulic economic dimensions (broken line) for channels having side slopes of $1\frac{1}{2}$ to 1.

such a wide range that the guide lines through any particular zone have not quite the same slant, but the results obtainable from any of these charts are more accurate than the agreement between preliminary figures and results of tests made after construction.

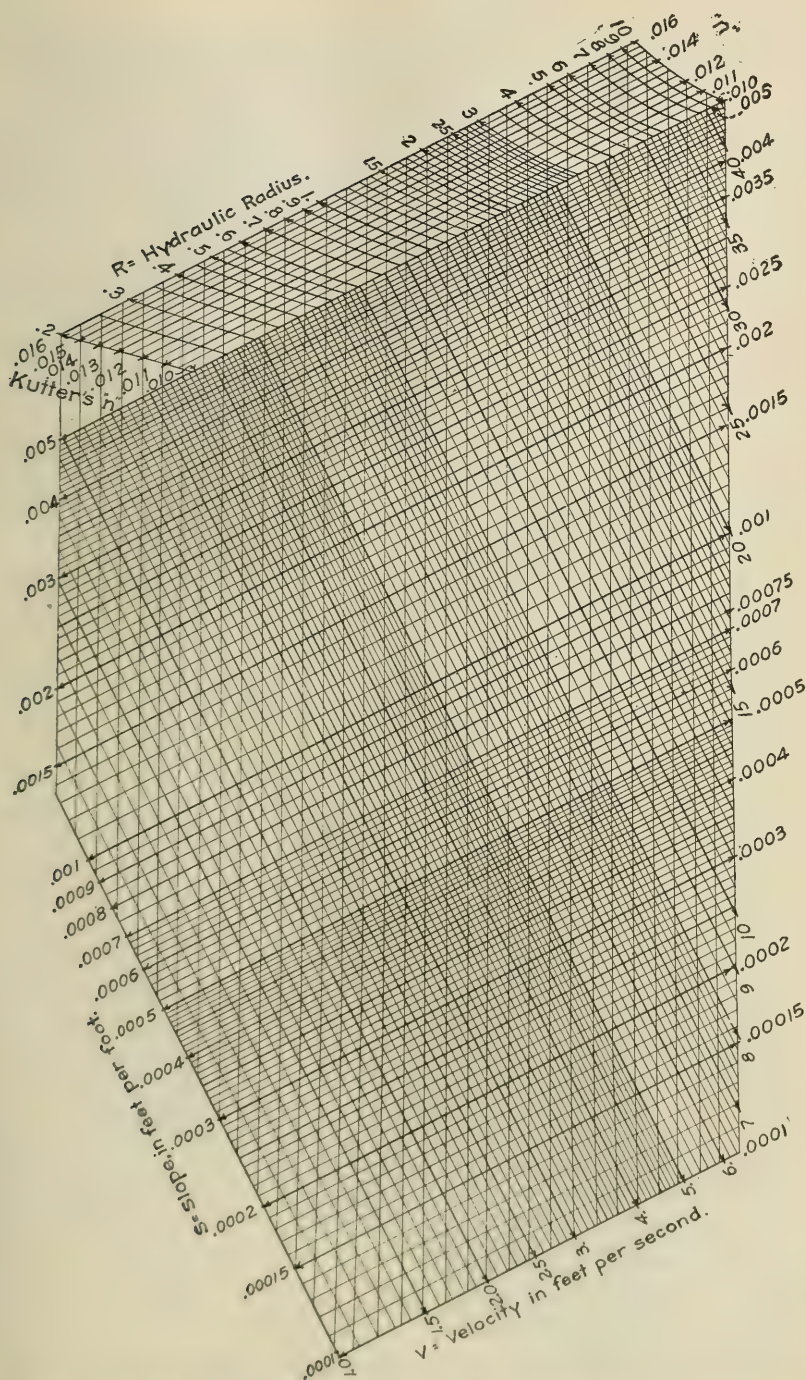


FIG. 6.—Chart for use in designing ordinary concrete, wood, or steel channels on moderate slopes.
From the intersection of R and n follow guide lines to intersection of S and V .

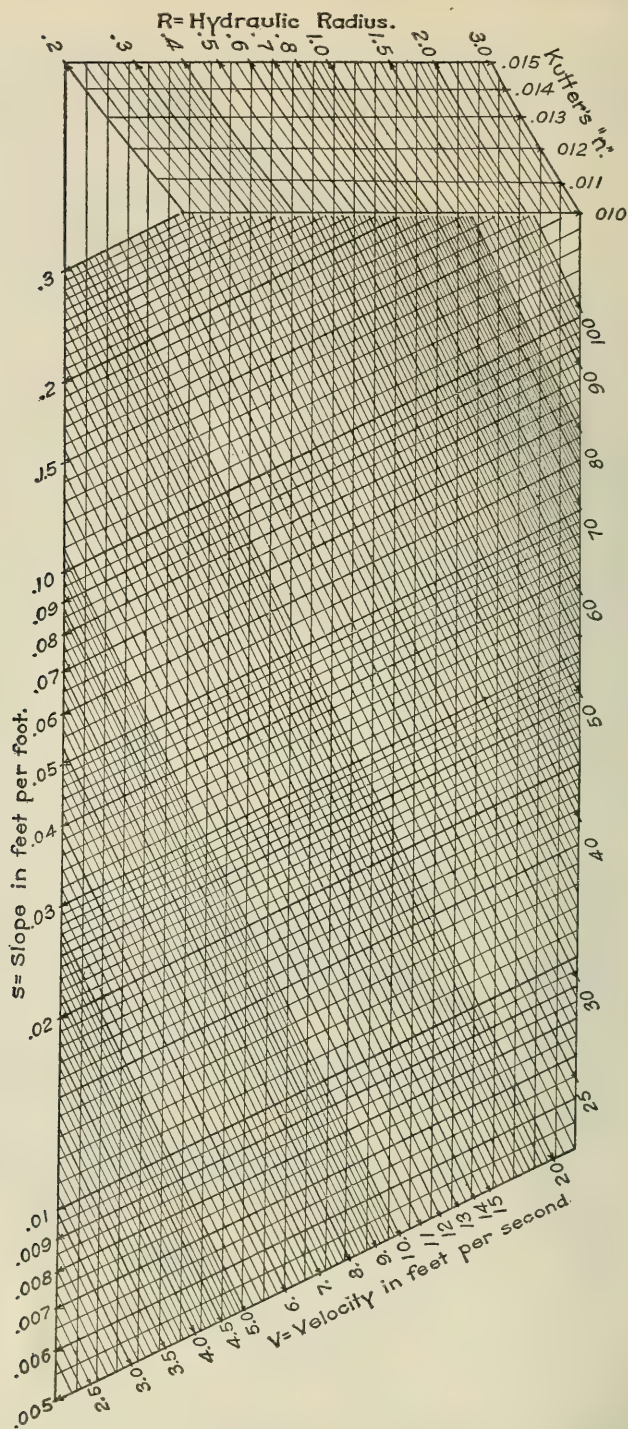


FIG. 7.—Chart for use in designing concrete, wood, or steel channels on very steep slopes; particularly for chute drops. From the intersection of R and n follow guide lines to intersection of S and V .

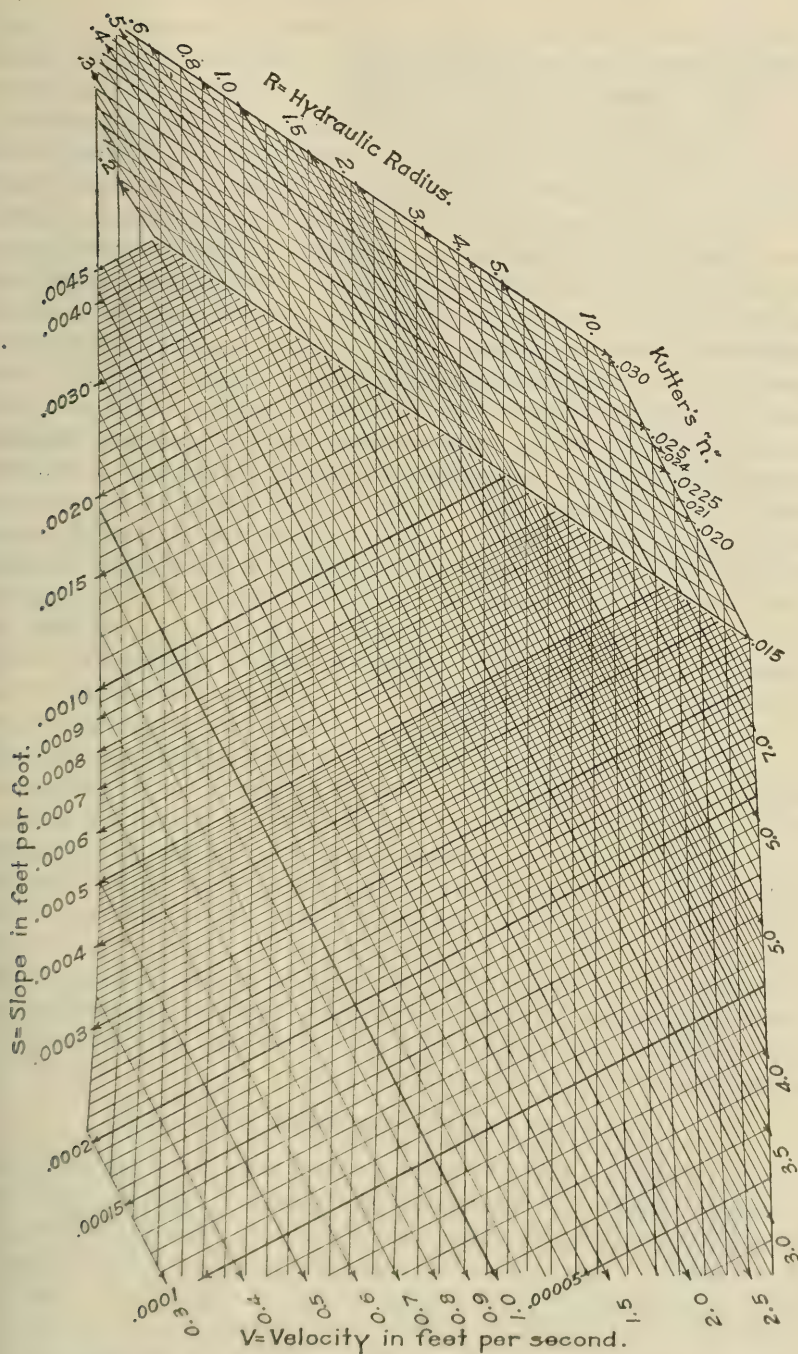


FIG. 8. — Chart for use in designing rough masonry, rough-coated concrete, or earth channels. From intersection of R and n follow guide lines to intersection of S and V .

Use of charts. Assume that it is desired to construct in well-made concrete a channel that will carry 1,000 second-feet of water at a mean velocity of 10 feet per second. Allow as a safety factor an overload of 5 per cent, making the designed capacity 1,050 second-feet. Therefore the area of such a channel must be 105 square feet. To test the possibilities of a rectangular cross section refer to figure 4. Any point on the "area" line representing a value of 105 will show values of depth, width, and hydraulic radius corresponding to this area, but the most economic channel—that is, the one having the least area for the greatest hydraulic radius—is at the point of intersection with the broken line. Therefore it is desirable to approach as nearly as possible to a channel 14.5 feet wide by 7.2 feet deep. A further study of the chart shows the hydraulic radius of such a channel to have a value of about 3.6 feet. Assume that the character of the lining, curvature, and so on should give a value of n of 0.012. Turning to figure 6, follow a line parallel to the guide lines from the point of intersection of n equals 0.012 and R equals 3.6 feet. This line intersects the velocity line equal to 10 feet per second on a slope line equal to 0.00122 feet per foot. But suppose the topography of the land to be such that a slope of 0.00122 is not obtainable or is not desirable. Suppose the best location for a canal is on a slope of 0.0015 feet per foot. The intersection of 10 feet per second velocity line with 0.0015 feet per foot slope line is down the guide lines from the intersection of n line of 0.012 and hydraulic radius line of 3.1. With this value for hydraulic radius go back to figure 4, and the intersection of area line 105 square feet and hydraulic radius line 3.1 shows the water section of the necessary channel to be 25.5 feet wide and 4.1 feet deep, while the same intersection on figure 5 gives a trapezoidal channel 19 feet wide on the bottom and 4.2 feet deep.

Figures 6, 7, and 8 may be used for the general solution of problems involving Kutter's formula. Given any three of the variables—slope, radius, n and velocity, and the fourth may be determined as accurately as is warranted.

VARIATIONS OF n IN THE SAME CHANNEL.

It is well known that the same channel does not necessarily have the same value of n throughout the season. Vegetable growths, especially moss, may so change the value of n from early spring to the middle of summer that the channel may carry but 75 per cent of its rated capacity for the same depth of water in the channel. The writer made a series of current-meter measurements on a prominent canal near North Yakima, Wash., during the month of July, 1914. The canal was rated and had carried more than 70 second-feet when clean in the spring, but in July it carried but 62 second-

feet, although running bank full. The velocity was retarded by moss accumulations. As the total capacity of the canal is needed throughout the season, it would have been better to design this concrete channel for a value of n about 0.017 for moss and sharp bends than to use a value of 0.012 as was done. A high velocity would have resulted during the months when the canal was cleaned, but this would not have injured the concrete and might have delayed the deposit of moss, although this is doubtful.

Some writers have contended that the value of n decreases as velocity or hydraulic radius increases, the condition of channel remaining the same. Wherever the experiments tabulated in Table I contained more than one test in the same reach of channel at the same time of year (approximately the same date) the writer has plotted the results shown in figure 9 and connected comparable points by broken lines. Values of n as abscissæ and V as ordinates

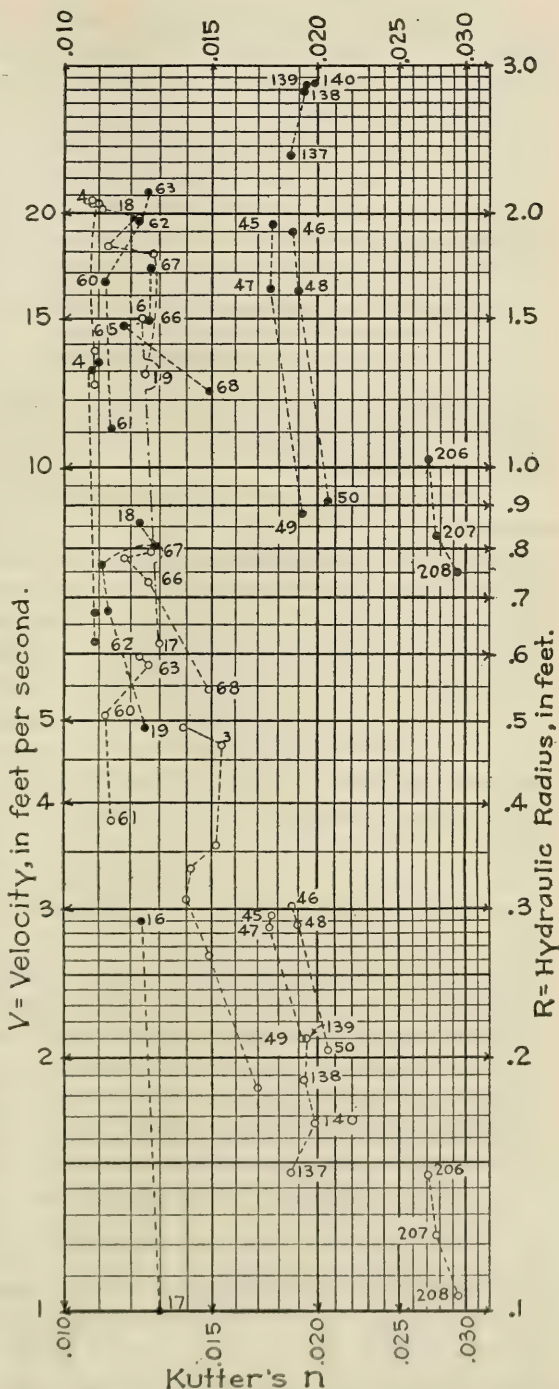


FIG. 9.—Diagram showing variation of n with varying velocities (open circles) and with varying hydraulic radii (dots) as the discharge is varied in the same reach of the same channels at the same time of year.

are designated by open circles and numbered to correspond with the numbers in column 1, Table I. For the same tests the values of R as ordinates are also plotted as dots. As a general statement there is a distinct tendency for n to decrease as the velocity and hydraulic radius increase, although in some cases the opposite effect is noted. The slope of the decrease in n is rather uniform, but the writer did not feel that the evidence was sufficient to attempt to deduce a formula to cover it.

A chart showing this change for values of n usually assigned to earth channels has previously been published.¹

CONCLUSIONS.

A careful study of the data on the previous pages and of the experiments carried out by others appears to warrant the following general conclusions:

(1) That Kutter's formula is applicable to the design of any open channel.

(2) That the recommendations of the earlier writers concerning the values of n to be chosen were in the main correct. Any weakness was due to the fact that there was not sufficient distinction made between the various categories and that materials of construction are now used which were not covered by the tests from which early deductions were made. The influence of curves was not as a rule included. Concrete lining covered but one value of n , whereas in practice there are many shades of roughness, all applicable under the general head of concrete.

(3) That the factor n must include all the influences which tend to retard velocity. The principal of these influences are undoubtedly (a) rubbing friction between the water and the containing channels, and (b) vegetable growth extending into the main body of the water. The lack of carrying capacity in many channels is probably due to the fact that the first influence was the only one considered. Of secondary importance, but nevertheless deserving of careful consideration in about the order named, are the following: (c) Angles and sharp curves in the alignment. (d) Influences which tend to disturb parallel filaments of current. The concrete lining in a rough rock cut may be quite smooth to the feel of the hand and yet be so undulating as to cause heavy cross currents which retard velocity. All projections and irregularities in the bank of a canal disturb the filaments of current in addition to having a large area exposed to rubbing friction. (e) Sand and gravel cause heavy loss in velocity when allowed to enter and accumulate in shifting patches on a lined canal bed. Fine sand drifts downstream in deep, irregular pockets and

¹ C. T. Johnson and R. D. Goodrich. A Formula and Diagram for Determining the Velocity of Flow in Ditches and Canals. Engin. Rec., 64 (1911), No. 19, p. 542.

may entirely change the character of the bottom of a smoothly lined canal. On the other hand, a water laden with fine silt flows far more freely after the silt has deposited in a slick coat over minor irregularities than in a new, though clean, canal. A canal carrying such a water may be designed for a far higher velocity through the same kind of soil than would be the case if the water were clear. It is necessary only to run but low heads in the new canal until a thick waxy deposit has been placed on the canal bed, after which the velocity may be nearly doubled over that which would have scoured the material in which the canal was originally excavated. (f) The prevailing wind direction may be given some consideration. A study of vertical velocity curves shows a marked change in form with change in wind condition. A downstream wind aids the flow of surface water to the extent that it has the maximum velocity in the vertical, while an upstream wind so shapes the velocity curve that the surface velocity is as slow as that near the bottom.

(4) That there is a tendency toward a lower value of n as the velocity and hydraulic radius increase. Any experiments that are intended to bring out conclusively the extent of the variation and whether it is due to the change in velocity or the change in hydraulic radius must be conducted in very long, straight channels, in wood, or concrete, or steel, where the character of the wetted perimeter will remain unchanged as the water becomes deeper and deeper in the channel. Proper corrections must be applied for any slight changes in the mean velocity at the two ends of the reach tested. The reach must be far removed from all influence of curves and structures.

(5) That a value of n must be chosen that will apply to the canal in question at the critical period of the season. For instance, most canals are cleaned once a year. A growth of moss may become very heavy by July or August, but the water supply or demand will probably be much less than during the early days of June. If the canal is designed to carry its peak load on the basis of its being in good condition, there will still be sufficient carrying capacity for the smaller discharge when moss has appeared.

(6) That in the design of earth channels having a trapezoidal form when constructed, the value of R should be computed on the basis that the canal takes an elliptical form within a short time and thereafter maintains this shape unless altered artificially.

ACKNOWLEDGMENTS.

The writer and his associates desire to acknowledge indebtedness to the various engineers and managers of irrigation and power systems who permitted the use of canals under their charge for the tests and to the engineers of the United States Reclamation Service who allowed access to much original data on tests made by their engineers.

APPENDIX.

The following pages are devoted to abstracts of descriptions of canals on which tests have been made in recent years by other agencies than irrigation investigations of the Office of Experiment Stations. The first number refers to the corresponding number in Table I, page 19. Next follows the symbol referring to the experimenter, as listed on page 16. Tests marked * are described in detail in Engin. News, 57 (1907), No. 23; those marked ** are described in United States Geological Survey Water-Supply and Irrigation Paper 43 (1901); those marked *** are described in United States Reclamation Service Reclamation Record, 4 (1913), No. 7; those marked + are described in Colorado Station Bulletin 194 (1914); those marked ++ are described in University of Colorado Studies, 7 (1910), No. 4.

CONCRETE LININGS.

No. 2, R. S., 14***, main canal, Boise project, United States Reclamation Service. Rather rough, in places disintegrated by frost. Fairly clean but still some rock in bottom. Other tests in same section gives values of n from 0.0129 to 0.0148. Coefficient $n=0.0130$.

No. 3, R. S., 8***, main canal, Boise project, United States Reclamation Service. Rough troweled. Small deposit rocks and gravel in bottom. Coefficient $n=0.0154$.

No. 4, R. S., 36***, Sulphur Creek wasteway, Sunnyside unit, United States Reclamation Service. This covers one of four tests in same section, with discharges from 45 to 247 second-feet. Corresponding values of n are the same, within 0.0002 for all discharges. Wood forms used; no retouching of surface. Circular section, radius 4 feet. Coefficient $n=0.0108$.

No. 5, R. S., 33***, Sulphur Creek wasteway. Similar to No. 4 above, but on 2° curve. One of three tests with discharges from 52.5 to 247 second-feet. Corresponding values of n same within 0.0004. Coefficient $n=0.0140$.

No. 6, JBL-6*, main supply conduit for Los Angeles, Cal. Covered conduit. In use four years, one curve in section tested. Where wetted, section was very smooth. Apparently of 1 to 3 cement-mortar plaster on concrete. No deposit or growth. Coefficient $n=0.0108$.

No. 7, JBL-5*. Description and reach tested same as No. 6 above. Coefficient $n=0.0111$.

No. 8, JBL-2*, tunnel 23, San Gabriel plant of Pacific Light & Power Co., California. Covered conduit. In use eight years. No growth. Deposit conditions indeterminate. Slight curves near each portal. Slope determined by correcting office notes of floor grade by depths of water. Coefficient $n=0.0113$.

No. 9, VMC+, Dry Creek flume, Handy Canal, Loveland, Colo. In good condition. Lined in 1906 with cement mortar, trowel finish. Coefficient $n=0.0115$.

No. 10, JBL-1*, tunnel 15, San Gabriel plant, Pacific Light & Power Co., California. A tunnel similar to No. 8 above. Slight curve at upper portal. Sharp angle 20 feet below lower portal. Deposit conditions indeterminate. Coefficient $n=0.0128$.

No. 15, R. S., 20***, Ridenbaugh Canal, Idaho. Description similar to Nos. 12-13 in text. One of three tests with discharges 50, 103, and 230 second-feet. Corresponding values of n are 0.0132, 0.0130, and 0.0122.

No. 16, R. S., Lizard chute, Boise project, United States Reclamation Service. Straight, very smooth and uniform. Sides battered 1 in 12. Meter measurement in canal below chute. The chute is 900 feet long, in three slopes. Coefficient $n=0.0124$.

No. 17, R. S. Same section as No. 16 above with different discharge. Coefficient $n=0.0130$.

No. 18, VMC+, Long Pond chute near Fort Collins, Colo. A reinforced concrete chute carrying water on steep grade at velocities from 12 to 20 feet per second. Constructed in 1910. Meter measurements made in 1912 near inlet in lower velocities. Elements determined by measurements down from bench marks to top and bottom of pulsations. Mean of these two measurements accepted. These tests two of five, made with discharges ranging from 35.79 to 122.94 second-feet. The values of n range inconsistently from 0.0125 down to 0.0111 for discharge of about 104 second-feet and then back to 0.0123 for the greatest discharge.

No. 19, VMC+. Same channel and reach as No. 18 above. Coefficient $n=0.0125$.

No. 20, R. S., 5***, Umatilla project, United States Reclamation Service. Smooth, regular, section on a slight curve. Coefficient $n=0.013$.

No. 21, R. S., 1***, Umatilla project, United States Reclamation Service. Circular, 4.9 feet radius. As left by wood forms. On tangent. Coefficient $n=0.0132$.

No. 22, R. S., 4***. Same conduit but on curve of 100 feet radius. Coefficient $n=0.0142$.

No. 23, R. S., 3***. Same conduit but on a curve of 50 feet radius. Coefficient $n=0.0189$.¹

No. 24, R. S., Arena chute, Boise project, United States Reclamation Service. Straight, very smooth and uniform. Sides battered 1 in 6. Meter measurement in canal below chute. Coefficient $n=0.0139$.

No. 32, VMC+, South Canal, Uncompahgre project, United States Reclamation Service, Colorado. This and the following two tests made on short sections between curves. Gives experience on steep grades, in lining as left by forms with boards laid longitudinally. Canal carrying less than one-tenth rated capacity. Coefficient $n=0.0155$.

No. 33, VMC+. Same canal and description as No. 32 above. Coefficient $n=0.0158$.

No. 34, VMC+. Same canal and description as No. 32 above. Coefficient $n=0.0171$.

No. 36, JBL-8*, Santa Ana Canal, near Yorba, Cal. Concrete tamped behind board forms. No plaster coat. Section wide and shallow. Several inches of sand in bottom. Moss and grass in patches on sides. Coefficient $n=0.0157$.

No. 39, JBL-7*, Colton Canal, near Colton, Cal. Lining of unplastered concrete. No sand or gravel. Sides and bottom covered with thin coat of moss. Coefficient $n=0.0167$.

No. 52, JBL-4*, Upper Canal, Riverside Water Co., California. Coat of 1 to 3 cement plaster roughly applied to concrete. Canal partially cleaned of a stringy grass a few days before test. Isolated bunches of grass left in bottom. Two curves included in reach. Coefficient $n=0.0218$.

No. 56, JBL-3*, Riverside Canal, California. From 1.5 to 2.5 feet of sand in bottom of canal lined with 1 to 3 plaster coat on concrete. Top sand shifting downstream (see No. 55). Sides covered with feathery grass sometimes 1 foot long. Containing boundary 75 per cent shifting sand and 25 per cent water grass. Two curves in reach. Canal equivalent of earthen channel with loose sediment bottom. Coefficient $n=0.0284$.

¹ Details of above three tests in Engin. News, 69 (1913), No. 18, p. 904.

WOODEN FLUMES.

Nos. 60, 61, 62, 63, VMC+, Orchard Mesa Power Canal near Palisade, Colo. Lumber, planed, with tongued and grooved joints and with vertical pieces of 2 by 4 inch lumber in nearly all sections to check velocity in low discharge to keep flume wet. Straight reaches from less than 100 up to 600 feet long, joined at angular turns. Flume built in 1909-10. Has sagged below grade 0.3 foot in places. Of 22 reaches tested 17 show higher values of n for highest than for lowest discharge. The average value of n was 0.0122 for 75 tests on 22 reaches.

No. 69, R. S., Fargo drop, Boise project, United States Reclamation Service. Smooth planed plank coated with tar. Coefficient $n=0.0122$.

No. 76, SF-23**, Bear River Canal flume over Malad River, Utah. Test made on 125-foot wooden portion of flume. Reach above was 200 feet of iron and steel flume lined with riveted plates. Lower portion of planed wood. No gravel or sediment. Coefficient $n=0.0142$.

No. 81, VMC+, Oxford Canal, Fowler, Colo. Structure 23 years old. In good condition as to grade and alignment. Sides of 2 by 12 inch lumber battened with $\frac{1}{4}$ by 3 inch strips. Floor laid at right angles to axis of flume. Though apparently smooth, has a high frictional factor. Tendency to cause deposit of silt lessens leakage. Coefficient $n=0.0150$.

No. 92, SF-45**, small flume near Corinne, Utah. Planed lumber calked with oakum which projected in places. Coefficient $n=0.0184$.

No. 95, SF-8**, Bear River Canal, Utah. At mouth of Bear River Canyon. Originally of planed lumber, the floor was almost entirely covered with sediment and rock fragments. Coefficient $n=0.0201$.

No. 97, SF-10**, Bear River Canal, Utah. Located 2 miles above No. 95. Floor covered with sediment, gravel, and small cobbles. Coefficient $n=0.0217$.

METAL FLUMES WITH SMOOTH INTERIOR.

No. 98, VMC+, Minnesota Canal near Paonia, Colo. Grade not uniform. No transverse bracing, so flume sagged and took parabolic rather than semicircular form. This reach 200 feet long. On similar reach 70 feet long found n to be 0.0111, but this reach is too short for good test. Coefficient $n=0.0099$.

No. 99, VMC+, Garland Canal, Trinchera Irrigation District, Colorado. A new No. 168 flume in perfect alignment and excellently constructed. Coefficient $n=0.0101$.

No. 100, R. S., Boise project, United States Reclamation Service. This flume has a lap joint with smooth interior. It is 30 inches in diameter; was new and clean. Coefficient $n=0.0106$.

No. 101, R. S., Boise project, United States Reclamation Service. This flume has outside and inside stay rods. Interior smooth and clean. Semicircumference 80 inches long. Coefficient $n=0.0117$.

No. 102, R. S., Mora Canal, Idaho. Smooth, clean interior. Semicircumference 108 inches long. Coefficient $n=0.0112$.

No. 103, R. S., Yarnell lateral, Idaho. Smooth, clean interior. Semicircumference 72 inches long. Coefficient $n=0.0122$.

No. 104, VMC+. Another reach on flume No. 99 above. Same conditions. Coefficient $n=0.0126$.

METAL FLUMES WITH PROJECTING INTERIOR BANDS.

No. 105, R. S., Partridge lateral, Idaho. Semicircumference 48 inches long. Flume clean. Coefficient $n=0.0127$.

No. 106, R. S., Golden Gulch flume, Idaho. Semicircumference 108 inches long. Flume clean. Coefficient $n=0.0129$.

No. 107, R. S., Ten-Mile feeder, Idaho. Semicircumference 144 inches long. Flume clean. Coefficient $n=0.013$.

No. 108, R. S., South Ridge Canal, section 1, Idaho. Semicircumference 60 inches long. Flume clean. Coefficient $n=0.0139$.

No. 109, VMC+, King lateral extension, Uncompahgre project, United States Reclamation Service, Colorado. Excellently constructed as to alignment and grade. No. 108 flume. Coefficient $n=0.0179$.

No. 110, VMC+. Same system as No. 109 above. Same class of construction. No. 120 flume. Coefficient $n=0.0177$.

No. 111, VMC+. Same system as Nos. 109 and 110 above. Same class of construction. No. 96 flume. Coefficient $n=0.0166$.

METAL FLUMES OF CORRUGATED IRON.

No. 112, VMC+, Stewart Canal near Paonia, Colo. A No. 132 flume with numerous curves. Test in table covers whole flume. Value of n for portions of flume range from 0.0196 on a reach, most of which was on a curve of 300 feet radius to 0.0224 on a tangent. A similar test on a reach of No. 144 flume 278 feet long, with two curves, gave a value of 0.0230 for n . Coefficient $n=0.0222$.

MASONRY-LINED SECTIONS.

No. 114, R. S., Cottonwood flume, Idaho. Rubblestone fairly well laid. Some coarse sand in bed being carried as silt. Coefficient $n=0.0163$.

EARTH CHANNELS.

No. 118, W-14++, Interstate Canal, Nebraska. In same soil and with same general description as No. 120. This canal designed with frictional factor of 0.025, but on account of high velocity maximum discharge allowed is 830 second-feet instead of the 1,421 second-feet for which designed. Coefficient $n=0.012$.

No. 121, SF-21**, Bear River Canal, Utah. Canal six years old. Section changed from trapezoidal with 1 to 1 slopes to present form. Bottom covered with sediment, but free from gravel and growth. Coefficient $n=0.0134$.

No. 122, SF-12**, Bear River City Canal, Utah. Age and condition similar to No. 121 above of which this canal is a branch. Coefficient $n=0.0135$.

No. 123, SF-15**, Corinne branch, Bear River Canal, Utah. Reach free from growth. Originally trapezoidal in clayey loam now segment of ellipse lined with smooth silt. Six years old. Coefficient $n=0.0155$.

No. 124, SF-22**. Same canal as No. 123 above. Same conditions but carrying a small part of rated capacity. Coefficient $n=0.0164$.

No. 125, VMC+, Fort Lyons Canal, Colorado. Carrying but 7 per cent of capacity, merely covering bottom. Slight curves at ends of reach. Bottom fine silt, merging into sand. In places boggy. Exceptionally smooth, regular, and free from impediments. Coefficient $n=0.0165$.

No. 128, W-1b++, Empire Intake Canal, Colorado. Straight, grade uniform, channel in firm sand, and gravel having no pebbles larger than one-half inch diameter. No vegetation. Two years old. Coefficient $n=0.0170$.

No. 129, W-1++. Same reach as No. 128 above with different discharge. Coefficient $n=0.0194$.

No. 131, VMC+, Jarbeau Power Canal near Rifle, Colo. New. First third of reach in clayey loam with few water-worn stones projecting. Rest of reach in clayey loam in which moss was starting. Coefficient $n=0.0176$.

No. 136, SF-3**, Logan, Hyde Park and Smithfield Canal near Logan, Utah. In operation 15 years. Bottom and sides smooth earth and gravel up to 1 inch in diame-

ter with some pebbles 2 inches. Slight growth of grass on one side. In opinion of writer value of n is lower than might be expected. Coefficient $n=0.0184$.

No. 143, SF-13**, small lateral from Corinne Branch Bear River Canal, Utah. In good condition. Excavated in clayey loam. Now well lined with silt. Numerous footprints of stock in bed. Coefficient $n=0.0194$.

No. 144, SF-16**, Millville and Providence Canal. Constructed 33 years before test in compact clay dotted with small rock fragments one-half inch diameter. One side perfectly smooth, other side has willow roots. Few small cobbles in bed. Otherwise good condition. Coefficient $n=0.0195$.

No. 146, SF-17**, Logan and Hyde Park Canal in Logan, Utah. Bed of clay covered with thin layer of fine sand. About one-sixth of perimeter covered with low creeping water plant. (Value of n is lower than might be expected in opinion of writer.) Coefficient $n=0.0197$.

No. 147, VMC+, Mesa lateral a, Grand Valley Canal, Colorado. Carrying nearly full capacity. Bed lined with fine sediment. Sides rather uneven surface of clay loam. Short grass on bank was submerged one-half foot. Coefficient $n=0.0200$.

No. 148, SF-20**, Solveson & Co. Canal, Utah. Channel of small pebbles embedded in sand. Coefficient $n=0.0201$.

No. 150, SF-48**, lateral of Logan City Canal, Utah. Channel of pebbles size of a pea, embedded in finer material. No aquatic growth. Coefficient $n=0.0204$.

No. 152, W-3+++, Rist and Goss Ditch, Colorado. Built in heavy loam. Sides and bottom well coated. No weeds or aquatic growth. Coefficient $n=0.0204$.

No. 153, VMC+, Willcox Canal, Rifle, Colo. Bed of fine silt, sand, and pebbles, with thin scattering of 6-inch cobbles. Discharge tested less than one-twentieth of rated capacity. Coefficient $n=0.0205$.

No. 154, W-4+++, Old Barnes Ditch, Colorado. In good condition. Constructed in firm earth. Channel well coated with sediment. No stones or pebbles, but some long grass overhangs banks. Coefficient $n=0.0206$.

No. 156, SF-6**, Logan and Richmond Canal, Utah. Bed smooth and free from vegetation. Some indentations near top of channel. Coefficient $n=0.0211$.

No. 159, SF-4**, Logan, Hyde Park and Smithfield Canal, Utah. Channel composed of well-packed gravel, mostly of stones from 1 to 3 inches in diameter in equal proportion. (This value appears low to the writer.) Coefficient $n=0.0213$.

No. 163, SF-11**, Point Lookout Canal, Utah. When tested carrying about one-seventh of capacity. Channel smooth clayey loam lined with sediment. No vegetation in the reach, but some both above and below. Coefficient $n=0.0218$.

No. 165, VMC+, Bessemer Canal, Pueblo, Colo. Bed of smooth waterworn adobe. Coefficient $n=0.0219$.

No. 166, VMC+. Same canal as No. 165 above. Channel the same except for the presence of cottonwood tree rootlets at the sides. Coefficient $n=0.0281$.

No. 168, W-2+++, Loudon Ditch, Colorado. Bed has clean, sandy bottom without growth of any kind. Would be considered in fair condition. Coefficient $n=0.0220$.

No. 169, VMC+, Mesa lateral, Grand Valley Canal, Colorado. Bed smoothly lined with fine sediment. Sides of uneven loam. Short grass on bank submerged one-half foot. Coefficient $n=0.0220$.

No. 170, VMC+, Rio Grande, lateral 1-c, Del Norte, Colo. Description about the same as for No. 171, except that the gravel is finer. Coefficient $n=0.0221$.

No. 171, VMC+, Rio Grande, lateral 1, Del Norte, Colo. Bed varies from fine gravel to smooth round rocks about 6 inches in diameter. Coefficient $n=0.0390$.

No. 176, SF-19**, Lewiston Canal, Utah. At time of test carrying one-fourth rated capacity. Bed of smooth clay. About one-fifth of perimeter covered with frog moss. Coefficient $n=0.0224$.

No. 177, W-5++, Geo. Rist Ditch, Colorado. Originally excavated in material ranging from earth to coarse gravel with occasional cobbles up to 6-inch size. Bed lined with sediment. Banks uneven and overhung with sod. Coefficient $n=0.0224$.

No. 181, SF-31**, Providence Upper Canal, Utah. Coefficient $n=0.0229$.

No. 182, SF-14**, lateral of Bear River Canal, Utah. Originally excavated in clayey loam. Now bed covered with sediment. Patches of horsetail moss. Edges uneven. Coefficient $n=0.0230$.

No. 183, SF-39**, lateral 2, Bear River Canal, Utah. Conditions similar to No. 182 above except there was no moss and some bunches of grass along the edges retarded velocity. Coefficient $n=0.0230$.

No. 185, SF-9**, Walker Tract Canal, Utah. Channel in clayey loam free from vegetation. Low grade due to check dams in ditch. Coefficient $n=0.0232$.

No. 187, SF-1**, Providence Canal, Utah. In gravel size of peas with scattered pieces size of walnuts. No vegetation. Coefficient $n=0.0238$.

No. 188, SF-5**, College and City Canal, Utah. Bed of gravel from $\frac{1}{2}$ to 2 inch size embedded in finer material. Edges somewhat irregular with willow roots, otherwise no vegetation. Coefficient $n=0.0238$.

No. 189, SF-27**, Logan, Hyde Park and Thatcher Canal, Utah. Sides smooth with sediment. Bottom of earth, gravel, and pebbles up to $2\frac{1}{2}$ inches diameter. Coarser material covered one-fourth of perimeter. Coefficient $n=0.0246$.

No. 191, SF-18**, College and City Canal, Utah. No vegetation, but sides uneven. Bed covered with fragments of flat rock from $\frac{1}{2}$ to 2 inches in greatest dimension. Coefficient $n=0.0247$.

No. 196, SF-63**, Hyrum Canal, Utah. Sides of earth. One-half of perimeter across bottom covered with rock fragments up to 1 inch across. Weeds and alfalfa grew up to water's edge. Coefficient $n=0.0260$.

No. 201, VMC+, Rocky Ford Canal, Colorado. Bed of fine loose sand. Sides of clay with fine grass roots projecting. Some grass overhangs into water. Canal somewhat crooked and banks irregular. Coefficient $n=0.0266$.

No. 203, W-7++, Loveland and Greeley Canal, Colorado. Overhanging sod banks with grass in water. Earth channel with many cobbles up to 8 inches diameter. Reach tested on a curve. Coefficient $n=0.0267$.

No. 211, VMC+, Bessemer Ditch, Colorado. Bed of fine silt merging into clays with liberal sprinkling of loose stones up to 3 inches diameter. Coefficient $n=0.0280$.

No. 214, VMC+, Rio Grande lateral No. 1, Colorado. Bed composed of graded material from fine gravel to waterworn rocks 6 inches or more in diameter. Discharge was measured 1 mile above reach tested, and 2 per cent arbitrarily deducted for seepage loss. Three tests made on the same reach with discharge of 380 second-feet, 33.34 second-feet, and 27.16 second-feet, gave values of n as 0.0284, 0.0386, and 0.0370, respectively. This gives a lower value of n for the greater discharge.

No. 217, SF-42**, a central farm lateral of Bear River Canal, Utah. Bed of clay, with uneven cross section. Bunches of grass scattered along edges. Coefficient $n=0.0293$.

No. 218, SF-37**, a central farm lateral of Bear River Canal, Utah. A similar canal and section as that in No. 217 above. Coefficient $n=0.0295$.

No. 225, SF-64**, Hyrum Canal, Utah. Sides overgrown with alfalfa and weeds. Bed of coarse gravel up to walnut size. Coefficient $n=0.0319$.

No. 226, W-12++, Beasley Ditch, Boulder, Colo. Excavated in gravel and fine sand with a good many small cobbles. Banks held in place by logs laid parallel to stream. Coefficient $n=0.0320$.

No. 227, VMC+, Bessemer Canal, Colorado. Bed of fine silt, merging into clays with liberal sprinkling of loose stones up to 3 inches diameter. Coefficient $n=0.0321$.

No. 229, SF-55**, Smithfield Canal lateral, Utah. Cobbles partially covered with silt. Edges made irregular by cattle. Coefficient $n=0.0329$.

No. 232, SF-26**, Logan and Benson-Ward Canal, Utah. Bed of medium-sized gravel. Flow much impeded by horsetail moss which occupied about one-fourth of water section. Coefficient $n=0.0352$.

No. 234, W-9+++, Hillsboro Ditch, Colorado. In general bad condition. Irregular gradient. Banks rough. Gravel channel scoured by current. Coefficient $n=0.0371$.

No. 238, SF-62**, lateral of Hyrum Canal, Utah. Partially overgrown with alfalfa. Strip of moss on each side occupied about one-fifth of channel. Bed of flat fragments of rock, up to 3 inches greatest dimension. Coefficient $n=0.0393$.

No. 242, SF-24**, canal of Brigham City Electric Light Co., Utah. Well-formed canal. Bed of medium-sized unpacked gravel. One-third of water section filled with long waving water plants. Coefficient $n=0.0424$.

No. 246, SF-46**, Brigham City Canal, Utah. About half full of horsetail moss. Such bed as exposed is gravel. Edges overgrown with cress and weeds. Coefficient $n=0.0499$.

No. 247, SF-53**, lateral of Thatcher Canal, Utah. About two-thirds filled with horse-tail moss. Such bed as exposed is sediment. Coefficient $n=0.0519$.

No. 248, SF-52**, lateral of Thatcher Canal, Utah. About three-fourths filled with moss. Bed as exposed is fine sediment. Coefficient $n=0.0529$.

COBBLE-BOTTOM DITCHES.

No. 250, W-13+++, Beasley Ditch, Boulder, Colo. Channel of gravel on bottom with cobbles on the sides. On a slight curve with no vegetation in channel. General condition would be classed as good. Coefficient $n=0.0220$.

No. 256, SF-47**, Logan and Hyde Park Canal, Utah. Entire channel composed of loose coarse gravel up to hen's egg in size. Coefficient $n=0.0337$.

No. 257, SF-33**, lateral of Hyrum Canal, Utah. A case where water flows very slowly over a rough surface on steep grade. Bed composed of loose cobbles up to 3-inch size. Coefficient $n=0.0365$.

No. 258, SF-57**, lateral of Smithfield Canal, Utah. Canal on steep grade with bed composed of gravel and cobbles. Coefficient $n=0.0377$.

No. 260, SF-56**, lateral of Smithfield City Canal, Utah. Edges uneven. Bed of clean-washed gravel and cobbles. Coefficient $n=0.0423$.

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WILLIAM A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

May 20, 1915

POTATO BREEDING AND SELECTION

By

WILLIAM STUART, Horticulturist,
Office of Horticultural and Pomological Investigations

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Chief of Bureau, WILLIAM A. TAYLOR.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE



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INTRODUCTION.

The increasing commercial importance of the Irish potato as an article of human diet and its adaptation to widely varying climatic conditions have served to extend its cultivation throughout most of the agricultural sections of the United States.

Although the potato crop now ranks sixth in agricultural importance in the United States, it has by no means assumed the position that its wide use as a table food would seem to justify. Our present average annual production of potatoes is only about one-fifth that of Germany. This wide variation in production between Germany and the United States may be partially accounted for by the fact that 50 per cent or more of the German crop is used either for stock food or for conversion into starch, alcohol, or other industrial by-products. The American potato crop, on the other hand, has no such outlet for its surplus tubers, since less than 1 per cent of the crop is used for industrial purposes. Moreover, the per capita consumption of potatoes in Germany is about two and one-half times as great as it is in this country. These two factors account in large measure for the very

material variation between the total potato production of the two countries.

The modern tendency toward the development of potato-growing centers in widely separated sections of the United States, as, for example, Aroostook County, Me., the Norfolk and Eastern Shore trucking regions of Virginia and Maryland, the Red River Valley of Minnesota and North Dakota, the Kaw Valley of Kansas, the Greeley and Carbondale districts of Colorado, and the San Joaquin and Sacramento Valleys of California, has created a demand for varieties of potatoes especially adapted to cultivation in those sections. This condition, coupled with the presence of numerous diseases of the vines and tubers, from which frequent and oftentimes severe losses have resulted, has caused many inquiries to be made regarding the possibility of developing new varieties or strains possessing certain specific qualities not embodied, at least to the same degree, in those varieties now under cultivation.

This demand upon the plant breeder has served to emphasize the necessity, as well as the desirability, of attempting to develop, either through breeding or selection, new varieties or strains of potatoes which shall possess a greater degree of resistance to the parasitic fungi which now prey upon the plants and tubers. Another fruitful field of investigation well worth the attention of the plant breeder is the development of potato varieties that are better adapted to certain sections of our country. These adaptational characteristics may be either earliness or lateness, drought resistance or heat resistance, or an ability to succeed in heavy or in light soil; they may be productiveness, shape of tuber, quality of tuber, starch content, or, in fact, any distinct quality which would make a variety especially desirable for cultivation in a given locality.

POTATO BREEDING AND SELECTION DEFINED.

In order that there may be no confusion in the mind of the reader as to what is meant in this bulletin by the term "breeding," the writer has thought it best to make a clear-cut distinction between "breeding" and "selection."

Breeding is here employed in the sense of sexual reproduction.

Selection implies, in the case of the potato, the isolation and asexual propagation of desirable strains or types.

Breeding can only be successful when it goes hand in hand with selection. Selection, on the other hand, is not dependent upon breeding for results.

LIMITATIONS OF BREEDING AND SELECTION.

Broadly speaking, the limitations of breeding are not simply those found within the confines of our cultivated varieties of potatoes, but those embraced by the whole range of the tuber-bearing solanums.

In the case of selection, the limitations are those found within the varieties themselves.

Potato breeding, therefore, may be said to involve the raising of seedlings from hand-pollinated or self-fertilized seeds. It becomes intelligent breeding only when it deals with seedlings produced from hand cross-pollinated flowers protected from insects and borne on plants possessing certain characteristics which it seems desirable to combine in the resultant progeny. In other words, intelligent plant breeding requires the same careful consideration of the parent plants that is given to the selection of the male and female by the progressive up-to-date animal breeder. Selection plays a very important rôle in this kind of breeding.

EARLY ATTEMPTS AT POTATO BREEDING.

The first serious attempt at potato breeding in the United States of which the writer has any knowledge was made by Rev. C. E. Goodrich, of Utica, N. Y.¹ The incentive for this effort was furnished by the widespread occurrence of potato blight, both in this country and abroad, during the period between 1840 and 1847, and the consequent almost total failure of the potato crop in some seasons. In the opinion of Mr. Goodrich the apparent greater susceptibility of the vines and tubers to this disease was largely due to the lessened vigor of the plants, induced by long-continued asexual reproduction. He conceived the idea that the only way in which the vigor of the potato plants could be restored was by sexual reproduction. Through the kindly offices of the American consul at Panama a number of promising South American varieties of potatoes, presumably from Peru and Chile, were secured. A seedling grown from one of these plants in 1853, descriptively known as the Rough Purple Chili, was introduced into cultivation in 1857 under the name of Garnet Chili. Other introductions from the seed of these importations were the Amazon, Calico, Cuzco, Central City, New Kidney, Coppermine, Pink-eye, Rusty Coat, etc. Between the years 1849 and 1856 Goodrich raised 8,400 seedlings.²

The importance of Goodrich's work to the potato industry of this country lies not so much in the new varieties which he himself introduced as in the impetus he imparted to plant breeding and in the efforts of those who followed in his footsteps. Much of this zeal was the result of the origination and introduction of the Early Rose, a variety which was produced in 1861 by Albert Bresee, of Hubbardton, Vt., from a naturally fertilized seed ball of Goodrich's Garnet Chili. Thus there was obtained in the second generation from the imported South American potato, described by Goodrich as the

¹ Goodrich, C. E. Raising seedling potatoes. In *The Horticulturist*, n. s., v. 7, 1857, p. 273-276.

² Goodrich, C. E. *Op. cit.*, p. 276.

Rough Purple Chili because of its rough skin, purple color, and supposed place of origin, a variety which upon its introduction in 1867 did more to awaken a keen and widespread interest in potato breeding in America than any other variety which has since been produced. This statement is well substantiated by a perusal of our agricultural literature and the seed catalogues issued between 1867 and 1884. The same publications also show that this period was marked by greater activity and more painstaking efforts in potato breeding than have characterized the more recent years. The interest was greater, more work was accomplished, and the parentage of the new introductions was much more carefully recorded than has been the case in subsequent years. Since 1884 comparatively few of the introductions have been obtained from hand cross-pollinated seed. In the main they have sprung from naturally fertilized seed or have come as sports or mutations from varieties already in cultivation.

So far as the writer is aware, Goodrich did not attempt hand pollination of the potato blossoms, and in that respect he may be said to have failed in the performance of the highest type of plant breeding. His was a pioneer work which served to blaze the way for those who followed. Among the men who later took up the work may be mentioned C. G. Pringle, of Charlotte, Vt., and E. S. Brownell, of Essex Center, Vt.

The work of Pringle deserves rather more than passing mention, inasmuch as he brought to bear upon the problem all the skill that the then existing knowledge of plant breeding furnished. His was no haphazard work. He selected his varieties for crossing with a definite purpose in view. Each variety was supposed to possess one or more desirable qualities which it was proposed to combine by crossing with certain other desirable qualities of another variety. Not only were the varieties selected with a definite purpose in view, but equally as much attention was paid to the selection of particularly healthy and typical parent plants. So skillful did Pringle become in the breeding of potatoes that we find him contracting with a leading New York seedsman in the early seventies to produce hybridized potato seed at \$1,000 per pound. A considerable quantity of such seed was produced and through the agency of the seedsman was widely disseminated. There is every reason to believe that this seed, falling into the hands of amateur plant breeders, resulted in the production of a large number of promising new varieties. Of the potatoes which Pringle originated and which were introduced by B. K. Bliss & Sons, the Snowflake was perhaps most widely known. This variety was noted for its high table quality, but on account of a rather weak constitution and medium productiveness it became popular only as a family table potato.

Brownell originated many new varieties, but from what the writer was able to learn some years ago from his contemporary fellow workers it would appear that many of his seedlings were produced from naturally fertilized seed balls. Be this as it may, however, his productions were numerous and in their day were widely grown. Among the best known may be mentioned Brownell's Best, Beauty, Eureka, and Winner.

In this brief survey of the early attempts at potato breeding, it would scarcely be fitting to omit the names of a few other men who have gained a more or less enviable reputation through the origination of a variety or varieties which are still rather widely grown and who have exerted considerable influence on the development of the potato-growing industry of this country. Among these men are Alfred Reese, Luther Burbank, and E. L. Coy.

In 1870 Alfred Reese grew a seedling from a naturally fertilized seed ball of the Early Rose, which was introduced by Gregory in 1875 under the name of Early Ohio. This potato is perhaps more extensively grown at the present time throughout the central and middle Western States than any other variety. In fact, in certain sections, such as the Kaw Valley of Kansas, the Red River Valley of Minnesota and North Dakota, and in most of the early-market sections of the territory mentioned, it is almost exclusively grown. In the Early Ohio we have a third-generation seedling from Goodrich's imported Rough Purple Chili.

The early fame of Luther Burbank rests very largely upon the Burbank potato, which he originated in 1873. This potato was introduced by Gregory in 1876 as Burbank's Seedling. The story of its origin is not a record of any particular effort on the part of the originator. Indeed, according to Burbank's own version, it reads like this: In the summer of 1872, in a small plat of Early Rose potatoes in his mother's garden at Lancaster, Mass., Burbank observed one plant upon which a seed ball was developing. When he next visited the plant the berry was gone, but after diligent search of the ground in the vicinity of the vine he was fortunate enough to find it. The seeds of this berry were planted the following spring and from them grew 23 seedlings, one of which was later named Burbank's Seedling. In Burbank's Seedling we again have the third-generation progeny of the Rough Purple Chili.

E. L. Coy, of West Hebron, N. Y., is perhaps best known as the originator of the Beauty of Hebron, a variety which in its day was one of the most popular of the "medium earlies." Although the exact date of the origin of this variety is not known, it was probably about 1873 or 1874. It was introduced in 1878. Coy claims that the Beauty of Hebron was raised from a naturally fertilized seed ball of

the Garnet Chili, thus making it a second-generation seedling of the Rough Purple Chili.

In view of the testimony already presented regarding the parentage of a few of our better known varieties of potatoes, there seems to be every justification for claiming that Goodrich's efforts were epoch making.

TECHNIQUE OF POTATO BREEDING.

The floral organs of the potato are of such simple structure as to render the task of manipulating the flowers a comparatively easy one. The two organs immediately concerned in plant breeding are the pistil and the stamens. The potato plant bears perfect flowers; that is, each flower when normally developed has both pistil and stamens, or female and male organs of reproduction.

STRUCTURE OF THE PISTIL.

Each flower bears but one pistil. The style of the pistil varies from 6 to 9 lines in length and from one-third to two-thirds of a line in thickness. Generally speaking, the shorter the style, the more fleshy it is. Some styles are greatly curved, while others are only slightly so, and a few are perfectly straight. The 2-lobed stigma also varies very greatly in size. Some stigmas are very slightly enlarged and somewhat cup shaped, while others are considerably enlarged, having well-rounded lobes covered with short papillæ.

STRUCTURE OF THE STAMENS.

The potato flower normally possesses five stamens, though occasionally four or six have been noted. The stamens have short, thick filaments with large, fleshy, erect anthers which stand close together around the style, like a cone in the center of the flower (Pl. I, fig. 1, A). The placenta, which divides the anther longitudinally into two equal parts, is rather thick and fleshy. The halves or lobes of the anthers have small terminal pore openings, through which the ripe pollen grains normally escape. In many varieties, the anthers are so poorly developed that the terminal pores do not open, although they are not so undeveloped as to be devoid of pollen. In such cases the membranous outer covering of each lobe of the anthers may be slit open and the pollen grains scraped off into a watch glass by means of a scalpel, forceps, or needle.

The color of the stamens varies greatly with different varieties. Some are a pale lemon yellow, while others are a bright orange yellow, with all the intergradations of color between these two. Only one instance has come to the writer's attention in which the color of the stamens did not answer to the above description, and that was in the case of a wild Mexican species, *Solanum cardiophyllum lanceolatum* (Berth.) Bitter, where the anthers were chocolate brown with a

slight tinge of purple. Generally speaking, varieties with pale lemon-yellow flowers do not produce pollen freely and as a rule their pollen is not viable.

HAND TECHNIQUE.

The technique of cross-pollinating potatoes by hand is comparatively simple, but since relatively few of our commercial varieties develop viable pollen, the percentage of success is correspondingly small. Obviously the first step in the cross-pollination of the potato is the selection of the seed-bearing plants. Strong, healthy plants should be chosen for this purpose, of a variety possessing certain definite characters which it is desirable to combine with certain other desirable characters of another plant.

The next step is the selection and emasculation of the flowers and the bagging of the same. The proper stage at which emasculation should be performed is shown in Plate II, figure 1. This varies somewhat with the variety or species. Generally speaking, it should be done before the pistil protrudes through the bud, or a day or two in advance of the opening of the flower. The only instrument necessary for the removal of the stamens is a pair of sharp-pointed forceps. The operation is most easily accomplished by claspings the bud by the lower portion of the calyx with the forefinger and thumb of the left hand and then opening up and pushing back the corolla with a pair of sharp-pointed forceps; after this the stamens are easily removed by pressing each of them away from the pistil until the filament snaps off at its base. Plate I, figure 1, *B*, shows a potato blossom from which the stamens have been removed in this way. It is usually desirable to emasculate as many flowers in each cyme as are at the right stage of maturity. All the immature buds and mature flowers should be removed before inclosing the emasculated flowers in a paper bag (Pl. II, fig. 2). A 1-pound bag—that is, a paper sack having the capacity mark of 1 pound—is large enough for this purpose. To facilitate the work of putting on the bags, it has been found convenient to punch holes through the sides of the bags and to draw strings through these holes prior to going to the field (Pl. III, fig. 1). It has also been found desirable to inclose in the bag the young shoot bearing the flower cyme, or, where this is not feasible, to include as much foliage as possible around the flowers.

The flowers are usually ready for pollinating one to two days after emasculation, depending upon the stage of maturity when emasculated and upon the character of the weather subsequent thereto.

During the first few years in which the writer was engaged in potato breeding, various methods of removing the pollen from the anthers were practiced. One method was that of collecting in the early morning flowers from plants selected as pollen parents and bringing

them into the laboratory, where they were allowed to wilt slightly, after which it was generally found that the pollen could be jarred out of the terminal pores into a watch glass. In varieties which developed pollen sparingly, the cells of the anthers were opened and the pollen grains removed. Pollen secured in this way gave very indifferent results, as a rule, and the method was superseded by the one which is now in use.

The present method consists in gathering the flowers from the plants about as needed. When considerable numbers of crosses are to be made and when good flowers are abundant, a number of them are gathered from each male parent to be used. These flowers are kept in small paper bags similar to those used for covering the emasculated flowers, each bag being properly labeled with the name or field number of the variety. In this way the operator may carry a considerable quantity of readily available material with him. When pollen of any particular variety is desired, a flower is selected from the proper bag and the corolla is pushed back between the forefinger and thumb and held in such a way that the stamens lie directly across the thumb-nail. After removing the pistil, the anthers are tapped sharply with the forceps, and the pollen is jarred out, falling upon the thumb-nail (Pl. III, fig. 2), whence it is readily applied to the previously uncovered stigmas of the emasculated flowers (Pl. I, fig. 2). The bag is then replaced over the pollinated flowers, again inclosing as much foliage as possible. Usually the success or failure of the cross can be determined about one week after the pollen is applied. If there is a seeming affinity between the plants crossed and if an abundance of good viable pollen has been used, one will frequently find an almost full-grown seed ball at the end of seven days. As a rule, the crosses should be examined in five to seven days from the date of pollination. In most cases, at the expiration of this time, either the flower will have dropped off or the ovary will have swollen sufficiently to show that the cross has been successful. In such cases the paper bags should be removed and all seed balls that are developing should be inclosed in loose cheesecloth sacks, which should be securely tied to the stems of the plants. It is hardly necessary to say that a record should be made of each step in the process and that each cross should be properly labeled. In Plate IV a cluster of seed balls is shown and also lateral, sectional, and basal views of individual seed balls.

In connection with the methods just presented for the protection of the flowers from insect visitors or other possible sources of outside pollination, it should be stated that two leading plant breeders claim that it is unnecessary to cover the potato blossom. It has been suggested by one of these breeders that the flowers are

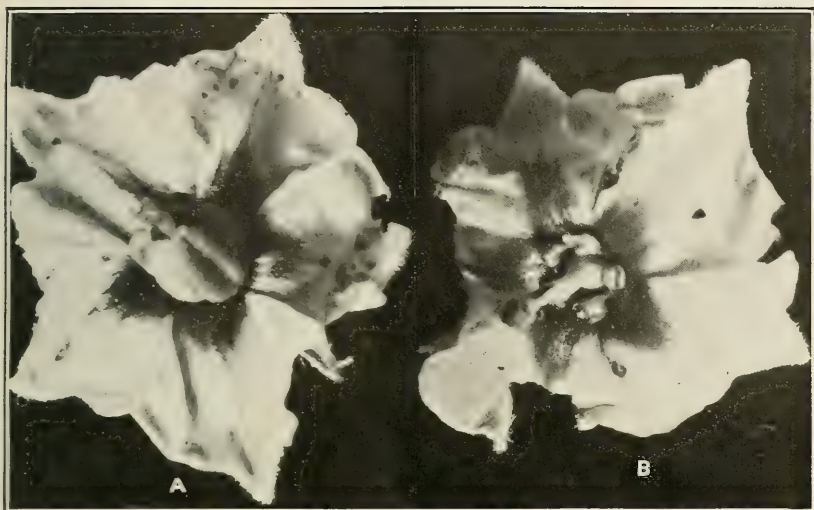


FIG. 1.—POTATO FLOWERS: A, BEFORE EMASCULATION; B, AFTER EMASCULATION.



FIG. 2.—FIELD OF POTATO PLANTS, SHOWING THE METHOD OF APPLYING POLLEN TO THE PREVIOUSLY COVERED STIGMAS OF THE EMASCULATED FLOWERS.

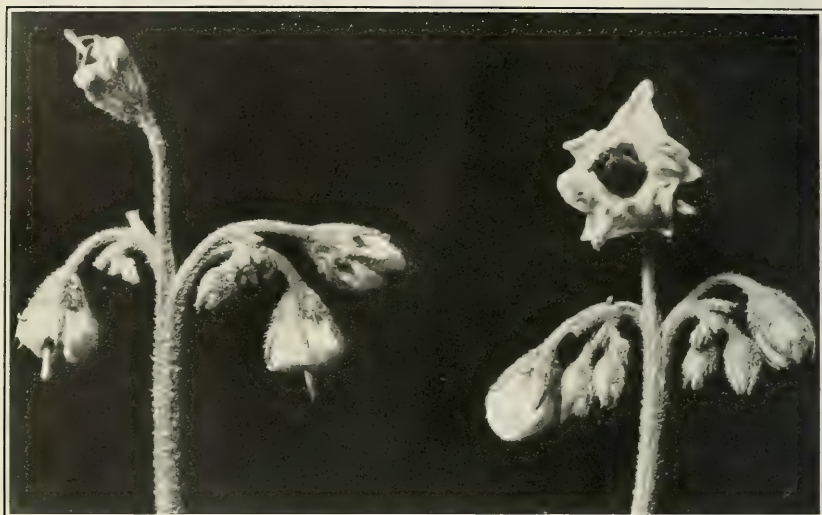


FIG. 1.—TWO POTATO FLOWER CYMES, SHOWING THE PROPER STAGE AT WHICH THE BLOSSOM SHOULD BE EMASCULATED.



FIG. 2.—THE SAME FLOWER CYMES SHOWN IN FIGURE 1 AFTER EMASCULATION. ALL IMMATURE BUDS AND MATURE FLOWERS HAVE BEEN REMOVED.



FIG. 1.—ONE-POUND PAPER BAG IN WHICH EMASCULATED POTATO FLOWERS ARE INCLOSED, SHOWING THE METHOD OF STRINGING.

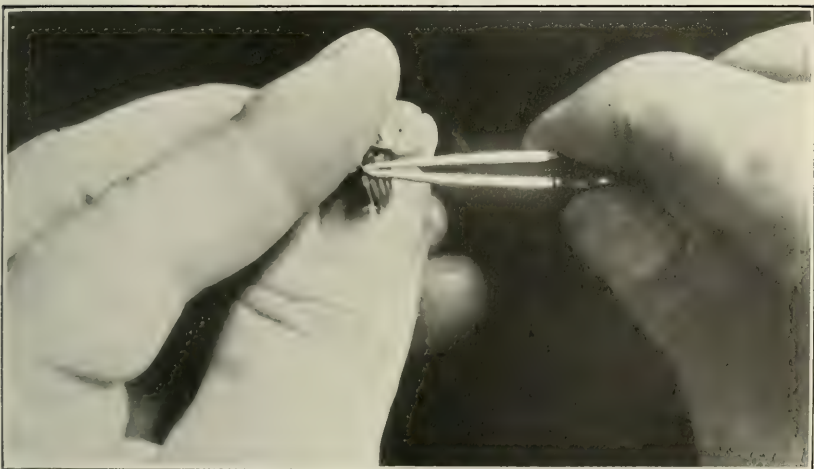


FIG. 2.—ANTHERS OF A POTATO BLOSSOM, SHOWING THE METHOD OF REMOVING THE POLLEN.

After the pistil is removed, the anthers are tapped sharply with the forceps and the pollen is jarred out, falling on the thumb nail.



POTATO SEED BALLS, SHOWING A CLUSTER, AND LATERAL, SECTIONAL, AND BASAL VIEWS.

much more likely to be broken off when inclosed in bags.¹ On this subject Salaman says:

All my work has been carried on without placing the flowers in bags. The reasons for not adopting special precautions were that when bagged the flower invariably drops, that bees and the like never approach a potato flower, though a small fly often lives in the bottom of the corolla, that the flower is constructed for self-fertilization, and that the quantity of pollen is so scanty as to render fertilization by the wind in the highest degree improbable.

East² makes the following statement regarding the covering of the flowers and emasculation:

We may conclude that if we cut off all the uppermost cymes from the plant stems and use for pollination only emasculated flowers of those borne next in order, the relative probability of our crosses being interfered with is negligible for all practical purposes. This removes the necessity of shutting out light and air circulation by means of bags. It is also worthy of note that the chances of success are much greater if the calyx and corolla are not removed during emasculation, as the style is very slender and is likely to be injured.

While the above assertions concerning the structure of the flower and the comparative absence of insect visitors are admittedly true, it has not been found that the bagging of the flowers necessarily causes a greater number of them to drop off, provided one follows the instructions already given and incloses a portion of the stem or foliage with the flowers. The beneficial effects of inclosing foliage with the flowers are believed to be twofold: (1) It serves to fill the sack and thus acts as a cushion for the flowers in windy or rainy weather; (2) the inclosure of so much foliage in a paper bag insures a goodly percentage of moisture from leaf transpiration and this indirectly prevents the drying out of the pistil and supplies favorable conditions for the germination of the pollen.

POLLEN-PRODUCING VARIETIES.

One of the chief difficulties confronting the potato-plant breeder is that a great many of our most desirable commercial varieties bloom either very sparingly or not at all and that few of those which do bloom develop viable pollen. In this connection East² makes the following statement:

If we regard blossoming as invariable at some period of their life under the proper conditions, we can then divide potato varieties into four classes:

1. Varieties whose buds drop off without opening.
2. Varieties in which a few flowers open but fall immediately.
3. Varieties whose flowers persist several days but rarely produce viable pollen.
4. Varieties which always produce viable pollen.

¹ Salaman, R. N. The inheritance of color and other characters in the potato. *In Jour. Genetics*, v. 1, no. 1, p. 7-46, 20 pl., 1910. (See p. 8.)

² East, E. M. Technique of hybridizing the potato. *In Proc. Soc. Hort. Sci.*, 1907, p. 35-40, 1908. (See p. 37.)

East estimates that about 60 per cent of the potato varieties belong to the first class and says that of the remaining 40 per cent only about 60 per cent have their blossoms persistent for more than a day. Our observations do not substantiate these statements, but this does not necessarily refute them if we regard East's data as applying merely to the particular locality in which his studies were made. The percentage of varieties belonging to any given class varies with the region and is very largely dependent upon the climatic conditions under which the plants are grown. In the opinion of the writer, most varieties will produce some blossoms when grown under optimum conditions for the normal development of the plant, particularly if these conditions prevail during the stage at which flower buds are formed. In any considerable varietal collection it is inevitable that many varieties should find the conditions unsuitable for their maximum development.

In studying the microscopic appearance of the pollen of different varieties, East¹ found that there was a great variation in the size and apparent vigor of the pollen grains. In describing them, he says:

Normal healthy pollen is round and about 36μ in diameter, while unhealthy pollen is scarcely ever over 20μ in diameter and is shriveled and irregular.

It was further observed that among the normal healthy pollen were some grains with from one to five slight protuberances which contained nuclei. It was also noted that the viability of the pollen was greater when these multinucleate pollen grains were present, and the suggestion is made that microscopic examination to determine the presence of such nuclei affords an easy and satisfactory method of determining whether the pollen of a given variety can be successfully employed.

The observations of East in regard to crosses have been fully corroborated by the writer, and further reference to them will be made in a later portion of this bulletin. The present almost total absence of seed balls on most of our commercial varieties, in the light of our present knowledge, is explainable on the basis that comparatively few of them develop viable pollen.

In a rather recent publication Salaman² announces that male sterility in the potato is a dominant Mendelian character. The data presented by Salaman would seem to amply justify this assertion. This evidence is in close harmony with what is actually encountered in the field, as it fully accounts for the striking scarcity of varieties which can be successfully employed as pollen parents.

¹ East, E. M. Op. cit., p. 40.

² Salaman, R. N. Male sterility in potatoes a dominant Mendelian character . . . *In Jour. Linn. Soc. [London], Bot., v. 39, no. 272, p. 301-312, 1910.*

RESULTS OF EXPERIMENTAL CROSSING.

Although many crosses were made by the writer prior to 1909, the results secured were of such a meager nature as to be unworthy of mention. In 1909, however, so many successful crosses were made as to cause the writer to inquire the reason thereof. This inquiry he has been unable to answer more satisfactorily than to suggest that it may have been due to more favorable growing conditions at the time the plants were developing buds and flowers, thus furnishing the right conditions for the development of viable pollen.

One of the main objects of the 1909 experiments was to secure as many crosses as possible between the disease-resistant German varieties and those American varieties which would cross with them. The anxiety to succeed was perhaps responsible for the use of a few undesirable pollen parents, which always afforded an abundance of viable pollen and could therefore be depended upon to effect a cross when all other sources failed. The abundant results secured served to convince the writer of two facts which had previously been rather puzzling: (1) It demonstrated conclusively that the ovaries and pistils of many of the varieties in the collection were normally developed and that lack of success was not due to this cause, and (2) it emphasized the necessity of paying greater attention to all varieties which produce viable pollen, as well as to those which produce it sparingly or not at all. A further observation was also made with respect to the secretion of stigmatic fluid by the glands of the stigma. Practically every writer who has had occasion to describe the potato flower in connection with the subject of plant breeding has told his readers that the stigma is in a receptive condition when it is covered with a fluid secretion. This condition of the stigma has rarely been observed and then only when the pistil has passed beyond the stage of successful fertilization. It is doubtful whether the secretion of a stigmatic fluid is a normal function of the potato blossom at the present time.

The accompanying record of the 1909 crosses, which is presented as Table I, gives the parentage, number of flowers crossed, number of seed balls developed, percentage of success, and the number of seedlings that produced tubers.

A study of Table I discloses some rather interesting data, particularly with respect to the behavior of seed-bearing plants when pollinated with different varieties. In the first cross recorded, Geheimrat Theil $\times$ Keeper, six flowers were pollinated and five seed balls were developed, from which 502 tuber-bearing plants were produced. The same variety when mated with XX Early developed only one seed ball from 11 pollinated flowers, and this did not produce a single tuber-bearing plant. When crossed with *Solanum maglia*, a wild South American species, it failed to set fruit, and the same negative

results were obtained when pollen of the unnamed Mexican species of *Solanum* was used. We know that *S. maglia* produces pollen very sparingly and that frequent attempts to germinate the pollen in the laboratory have been unsuccessful. The Mexican species is known to produce viable pollen in abundance, however, so that in this case the failure to set fruit was probably a clear example of nonaffinity. The next female parent, Sophie, crossed with Keeper, gave excellent results. Sophie is a German variety possessing qualities of vine and tuber strongly resistant to late-blight. From 20 pollinated flowers 16 seed balls were developed. The seeds from the 16 seed balls produced 2,244 tuber-bearing plants, or an average of 140.3 plants per berry. The 4 pollinated flowers of Sophie × Fuerst Bismarck failed to develop a single berry. A similar result was obtained from 8 flowers pollinated with Empire State and from 4 pollinated with Garnet Chili. Sophie × Irish Seedling produced 4 seed balls from the 4 flowers pollinated. The seeds from these berries gave 707 tuber-bearing plants, or an average of 176.8 plants per berry. Three flowers pollinated with Venezuela failed to set fruit. It is clearly evident that the varieties Fuerst Bismarck, Empire State, Garnet Chili, and Venezuela either did not develop viable pollen or the pollen tubes were unable to reach the ovules of the flower. It is known that all of these varieties produce pollen sparingly, and it is probable that an insufficient quantity of viable pollen was present to effect the cross.

TABLE I.—Record of potato crosses made at Burlington, Vt., in 1909.

Parentage of cross.	Number of flowers crossed	Number of seed balls developed.	Percentage of success.	Number of tuber-bearing seedlings.	Average number of seedlings per seed ball.
Geheimrat Theil × Keeper.....	6	5	83.3	502	100.4
Geheimrat Theil × XX Early.....	11	1	9.1	0	0
Geheimrat Theil × <i>Solanum maglia</i>	3	0	0	0	0
Geheimrat Theil × <i>Solanum</i> sp. ¹	2	0	0	0	0
Sophie × Keeper.....	20	16	80	2,244	140.3
Sophie × Fuerst Bismarck.....	4	0	0	0	0
Sophie × Empire State.....	8	0	0	0	0
Sophie × Garnet Chili.....	4	0	0	0	0
Sophie × Irish Seedling.....	4	4	100	707	176.8
Sophie × Venezuela.....	3	0	0	0	0
Professor Maerker 506 × Apollo.....	12	9	75	275	30.6
Professor Maerker × Early Silverskin.....	15	15	100	555	37
Professor Maerker × Keeper.....	13	12	92.3	326	27.2
Professor Maerker × Rand's Peachblow.....	4	0	0	0	0
President Kruger × Apollo.....	8	4	50	159	39.8
President Kruger × Gem of Aroostook.....	13	0	0	0	0
President Kruger × Green Mountain.....	8	0	0	0	0
President Kruger × Keeper.....	11	9	81.8	640	71.1
President Kruger × Star of the East.....	8	0	0	0	0
President Kruger × <i>Solanum tuberosum</i> Lind.....	21	0	0	0	0
Fuerst Bismarck × Apollo.....	12	5	41.7	188	37.6
Fuerst Bismarck × Harris Snowball.....	5	0	0	0	0
Fuerst Bismarck × June.....	3	0	0	0	0
Apollo × Early Silverskin.....	16	4	25	50	12.5
Apollo × Empire State.....	8	0	0	0	0
Apollo × Irish Seedling.....	7	3	42.9	243	81
Daisy × Keeper.....	5	4	80	453	113.3
Daisy × Early Silverskin.....	12	5	41.7	329	65.8
Daisy × Round Pinkeye.....	8	4	50	180	45

¹ Mexican species.

TABLE I.—Record of potato crosses made at Burlington, Vt., in 1909—Continued.

Parentage of cross.	Number of flowers crossed.	Number of seed balls developed.	Percentage of success.	Number of tuber-bearing seedlings.	Average number of seedlings per seed ball.
Factor × Keeper.....	10	0	0	0	0
Factor × Gastold.....	5	0	0	0	0
Factor × Apollo.....	11	0	0	0	0
Factor × Keeper.....	16	0	0	0	0
Factor × Norcross.....	5	0	0	0	0
Factor × Alexander's No. 1 Red.....	8	0	0	0	0
Factor × <i>Solanum tuberosum</i> Lind.....	4	0	0	0	0
Factor × Round Pinkeye.....	7	0	0	0	0
Factor × <i>Solanum maglia</i>	8	0	0	0	0
British Queen × Star of the East.....	7	0	0	0	0
Up-to-Date × Fuerst Bismarck.....	9	0	0	0	0
Up-to-Date × Keeper.....	79	11	13.9	457	415
Up-to-Date × Norcross.....	3	0	0	0	0
Up-to-Date × Early Silverskin.....	12	2	16.7	50	25
Up-to-Date × Empire State.....	21	0	0	0	0
Up-to-Date × Irish Seedling.....	17	7	41.2	89	12.7
Up-to-Date × Round Pinkeye.....	14	3	21.4	75	25
Delaware × Keeper.....	13	11	84.6	537	48.8
Delaware × Round Pinkeye.....	58	9	15.5	388	43.1
Gem of Aroostook × Keeper.....	85	46	54.1	1,562	34
Gem of Aroostook × Rand's Peachblow.....	17	0	0	0	0
Gem of Aroostook × Round Pinkeye.....	114	55	48.2	1,873	34
Blight Proof × Fuerst Bismarck.....	9	0	0	0	0
Blight Proof × Apollo.....	10	0	0	0	0
Blight Proof × Early Silverskin.....	9	1	11.1	4	4
Blight Proof × Garnet Chili.....	4	0	0	0	0
Green Mountain × Apollo.....	20	4	20	102	25.5
Green Mountain × Keeper.....	15	3	20	90	30
Green Mountain × Early Silverskin.....	11	7	63.6	373	53.3
Green Mountain × Round Pinkeye.....	34	5	14.7	221	44.2
Green Mountain × Alexander's No. 1 Red.....	8	0	0	0	0
Green Mountain × Apollo.....	2	0	0	0	0
Harris Snowball × Fuerst Bismarck.....	16	0	0	0	0
Harris Snowball × Apollo.....	16	3	18.8	102	34
Harris Snowball × Early Silverskin.....	3	3	100	146	48.7
Harris Snowball × Round Pinkeye.....	10	6	60	127	21.2
Holborn Abundance × Apollo.....	8	3	37.5	561	18.7
Holborn Abundance × Early Silverskin.....	10	3	30	268	89.3
Holborn Abundance × Irish Seedling.....	14	9	64.3	778	86.4
Keeper × Fuerst Bismarck.....	15	3	20	0	0
Keeper × Keeper.....	7	2	28.6	30	15
Keeper × Norcross.....	5	2	40	13	6.5
Keeper × Early Silverskin.....	21	9	42.9	340	37.8
Keeper × Empire State.....	6	0	0	0	0
Keeper × Irish Seedling.....	13	7	53.8	121	17.3
Keeper × Round Pinkeye.....	14	9	64.3	227	25.2
Keeper × Venezuela.....	9	1	11.1	10	10
Norcross × Apollo.....	9	0	0	0	0
Norcross × Keeper.....	51	12	23.5	480	40
Norcross × Round Pinkeye.....	34	2	5.9	60	30
Rural New Yorker No. 2 × Early Silverskin.....	6	1	16.7	39	39
Star of the East × Round Pinkeye.....	62	26	41.9	990	38.1
Alexander's No. 1 Red × Irene.....	12	2	16.7	49	24.5
Alexander's No. 1 Red × Apollo.....	15	0	0	0	0
Alexander's No. 1 Red × Keeper.....	14	4	28.6	154	38.5
Alexander's No. 1 Red × Factor.....	6	0	0	0	0
Professor Maerker 652 × Apollo.....	12	5	41.7	122	24.4
Professor Maerker 652 × Keeper.....	4	3	75	66	22
Professor Maerker 652 × <i>Solanum tuberosum</i> Lind.....	44	0	0	0	0
Professor Maerker 652 × <i>Solanum maglia</i>	13	0	0	0	0
Professor Maerker 652 × Alexander's No. 1 Red.....	9	0	0	0	0
Rural Blush × Star of the East.....	4	0	0	0	0
Manly × Irene.....	11	5	45.5	242	48.4
Manly × Alexander's No. 1 Red.....	3	0	0	0	0
Early Excelsior × Apollo.....	14	6	42.9	133	22.2
Early Excelsior × Keeper.....	19	10	52.6	237	23.7
Early Excelsior × <i>Solanum tuberosum</i> Lind.....	27	0	0	0	0
Early Excelsior × Keeper.....	4	0	0	0	0
Early Excelsior × <i>Solanum tuberosum</i> Lind.....	5	0	0	0	0
Empire State × Fuerst Bismarck.....	6	0	0	0	0
Empire State × Keeper.....	9	6	66.7	144	24
Empire State × <i>Solanum maglia</i>	9	0	0	0	0
Garnet Chili × Keeper.....	0	1	11.1	38	38
Garnet Chili × Fuerst Bismarck.....	16	0	0	0	0
Garnet Chili × Early Silverskin.....	9	2	22.2	57	28.5
Garnet Chili × Rand's Peachblow.....	12	0	0	0	0
Round Pinkeye × Keeper.....	37	22	59.5	553	25.1
Venezuela × Keeper.....	12	8	66.7	457	57.1
Venezuela × <i>Solanum maglia</i>	3	0	0	0	0
Whiton's White Mammoth × Keeper.....	9	4	44.4	76	19

TABLE I.—Record of potato crosses made at Burlington, Vt., in 1909—Continued.

Parentage of cross.	Number of flowers crossed.	Number of seed balls developed.	Percentage of success.	Number of tuber-bearing seedlings.	Average number of seedlings per seed ball.
<i>Solanum utile</i> Klotzsch ¹ (wild) × Keeper	11	8	72.7	70	8.8
<i>Solanum utile</i> Klotzsch × Seedling 962	12	6	50	75	12.5
<i>Solanum utile</i> Klotzsch × Seedling 949	1	1	100	15	15
Total or average.....	1,599	458	28.6	18,947	41.4

¹ Called *S. utile* by Pierre Berthault, Recher. bot. sur le *Solanum tuberosum*. In Ann. de la Sc. Agron., 6th Ann., p. 181, fig. 1, 1911. Mexican species.

In the first cross of the third seed parent, Professor Maerker × Apollo, both the seed and pollen parents are of German origin, the latter being one of the most disease-resistant varieties in the collection. Nine seed balls are recorded from 12 flowers pollinated and 275 tuber-bearing plants were obtained from this lot, or an average of 30.6 plants per berry. Fifteen flowers pollinated with pollen from Early Silverskin produced 15 seed balls, from which 555 plants were obtained, an average of 37 plants per berry. When crossed with Keeper, 12 seed balls were developed from 13 flowers and these gave 326 plants, or an average of 27.2 plants per berry. Pollen from Rand's Peachblow proved ineffective.

It is interesting to compare the results from the two crosses, Sophie × Keeper and Professor Maerker × Keeper. In the first instance the percentage of success is 80 and in the latter 92.3. Carrying the comparison farther, however, we find that the first cross averaged over 140 plants per berry, while the latter averaged only 27.2. These data make it at once apparent that some varieties develop fewer ovules than others.

Two of the most interesting crosses in Table I are those of *Solanum utile* Klotzsch with seedlings 949 and 962, from which some 90 tuber-bearing plants were produced. *Solanum utile* is a wild Mexican species producing tubers rather sparingly on long, spreading stolons. The tubers rarely exceed or even reach the size of a small hen's egg and when well developed are of a purple color. Immature tubers do not show color, and owing to this characteristic Heckel¹ was led to conclude that he had secured a mutant when white-colored tubers were observed to produce colored ones. The seedlings of these two crosses, while varying considerably from the seed parent, nevertheless bore a very striking resemblance to it. A number of them made a much stronger and larger vine growth and produced larger tubers, some of which bore a more or less distinct resemblance to the pollen parent. Seed balls were borne rather sparingly on some of the seedlings. Up to the present time these seedlings offer little, if any, promise except in the possibility of their possessing greater resistance to disease.

¹ Heckel, É. M. Sur les Origines de la Pomme de Terre Cultivée, 82 p., illus., 8 pl. Marseille, 1907. (See p. 71.)

RECIPROCAL CROSSES.

In the reciprocal crosses presented in Table II, some additional light is shed upon the prolificacy of certain seed parents.

TABLE II.—Comparative behavior of reciprocal crosses of 1909 grown in 1910.

Parentage of cross.	Number of flowers crossed.	Number of seed balls developed.	Percentage of success.	Number of tuber-bearing seedlings.	Average number of seedlings per seed ball.
Keeper × Norcross.....	5	2	40.0	13	6.5
Norcross × Keeper.....	51	12	23.5	480	40
Keeper × Round Pinkeye.....	14	9	64.3	227	25.2
Round Pinkeye × Keeper.....	37	22	59.5	553	25.1
Keeper × Venezuela.....	9	1	11.1	10	10
Venezuela × Keeper.....	12	8	66.7	457	57.1
Keeper × Keeper.....	7	2	28.6	30	15

The reciprocal cross between Norcross and Keeper shows that when Keeper was fertilized with pollen from Norcross, 2 seed balls were secured from 5 flowers fertilized, and from these 2 seed balls 13 tuber-bearing plants were produced. When Norcross was crossed with Keeper, 12 seed balls were secured from 51 flowers crossed, and from these 12 seed balls 480 tuber-bearing plants were obtained, or an average of 40 plants per seed ball, as against 6.5 from the reciprocal cross. From these data we may either assume that Keeper is not as prolific a seed parent as Norcross or else that Norcross does not produce sufficient viable pollen. On the basis of the first assumption, we may compare the behavior of both seed parents to other pollen. Keeper when pollinated with Irish Seedling gave an average of 17.3 plants per seed ball (Table I), and when crossed with Round Pinkeye it produced 25.2 plants per berry. Norcross when crossed with Round Pinkeye gave an average of 30 plants per berry (Table I). This evidence would seem to indicate that the Norcross was a more prolific seed parent than Keeper; but it also points to the conclusion that Keeper is the best pollen parent, at least in so far as pertains to the production of viable pollen.

The reciprocal crosses between Round Pinkeye and Keeper are of considerable interest, owing to their apparent similarity. Keeper × Round Pinkeye gave 9 seed balls out of 14 blossoms fertilized and these averaged 25.2 plants per berry. Round Pinkeye when crossed with Keeper produced 22 seed balls from 37 flowers pollinated, and from these an average of 25.1 plants were produced. The rather low number of plants forming tubers from these reciprocal crosses would indicate that neither parent seemed to possess potency. Apparently, the mating of these two varieties was not a congenial one in either case.

In the reciprocal cross between Venezuela and Keeper, with Venezuela as the seed parent, 12 pollinated flowers developed 8 seed balls, from which an average of 57.1 plants was secured. Nine flowers of Keeper crossed with Venezuela resulted in but 1 seed ball,

from which 10 plants were obtained. It is evident from these figures that the pollen of Keeper was much more potent than that of Venezuela.

VARIETAL AFFINITY.

It is apparent to those familiar with plant breeding that certain types or strains of a given class of plants possess greater sexual affinity for each other than do other types or strains which are apparently as closely related. This phenomenon has been observed by potato breeders and has been taken advantage of in making crosses. One of the most interesting observations upon this point that has come to the writer's attention is that made by Taylor,¹ who says:

Careful experiments this season with that fine potato named Factor have proved that it is not only sterile to its own pollen, but also sterile to all the Up-to-Date type, of which class Factor is probably the best example. . . . It will cross with some of the colored-skinned varieties, which have also flowers of a similar tint, but the seed vessels mature very slowly and never attain a large size. Where pollen of white-flowered sorts can be obtained, such as the Admiral, Provost, Abundance, and Cumberland Ideal, a good set can be obtained on Factor and the pods soon attain full size; indeed, the growth of the so-called "plum" is remarkable in comparison with that of the others already noted . . . the pollen of Factor has been found to be absolutely sterile to some 30 other varieties of potatoes having flowers and tubers of different colors and none of them of the Up-to-Date class.

In this connection, Findlay² says of the Up-to-Date potato:

Its organs of reproduction are 90 per cent of them malformed. The stamens or pollen cases are small and never, so far as I have seen, contain one grain of pollen. The pistil is also of the same character. . . . the Up-to-Date potato beat me off so far as being able to effect my purpose, compelling me to fall back, as a last resource, on its male parent, or rather a natural seedling from the same. I then effected my object, and got two or three plums. But, as showing how much the Up-to-Date was off this job of seed production, the plums were small, containing few seeds, and of these few only about 53 per cent germinated.

The following data obtained from crosses made in 1909 seem to fully corroborate the observations made by Findlay with respect to the poor seed-bearing qualities of the Up-to-Date (Table I). From 155 hand-pollinated flowers of this variety, only 23 seed balls were secured, and one of this number was found to be seedless. The seeds secured from the 22 successful crosses produced only 671 tuber-bearing seedlings, or an average of a little over 30.5 tuber-bearing plants per berry. Seven pollen parents were used in making the crosses, and three of these, the Norcross, Empire State, and Fuerst Bismarck, did not produce a single seed ball. These are varieties that produce pollen very sparingly or not at all. Successful crosses were secured with Keeper, Early Silverskin, Irish Seedling, and Round Pinkeye, all of which produce pollen abundantly. The Irish Seedling gave the highest percentage of successful crosses (41.2 per cent), but for some reason produced a woefully small

¹ Taylor, G. M. The cross fertilization of the potato. *In* Gard. Chron., v. 48, 3d ser., 1910, p. 279.

² Findlay, A. The potato: Its history and culture. *In* North British Agriculturist, Jan. 25, 1905, p. 17.



FIG. 1.—POTATO SEEDLINGS 6 WEEKS OLD.



FIG. 2.—POTATO SEEDLINGS IN POTS, READY TO SET IN THE FIELD.



FIG. 1.—SETTING POTATO SEEDLINGS ON THE POTOMAC FLATS, WASHINGTON, D. C.,
IN 1911.



FIG. 2.—PLANTING 20,000 POTATO SEEDLINGS AT HONEOYE FALLS, N. Y., IN 1911.



FIG. 1.—POTATO SEEDLINGS ON THE POTOMAC FLATS, WASHINGTON, D. C., 1910.



FIG. 2.—STUDYING AND DESCRIBING THE PROGENY OF POTATO SEEDLINGS AT ARLINGTON FARM, WINTER OF 1910-11.



FIG. 1.—UNPROMISING FIRST-YEAR SEEDLING, CROP OF 1910.



FIG. 2.—ANOTHER UNPROMISING FIRST-YEAR SEEDLING, CROP OF 1910.

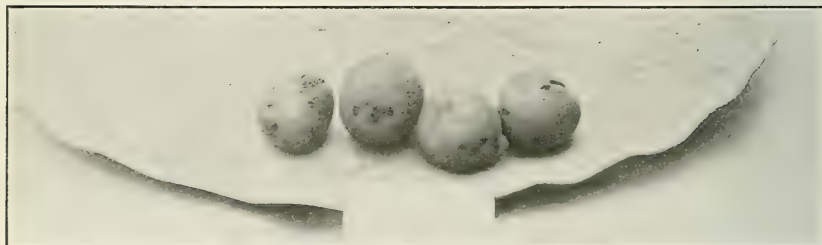


FIG. 3.—A LOW-YIELDING BUT NOT NECESSARILY UNPROMISING SEEDLING, CROP OF 1910.

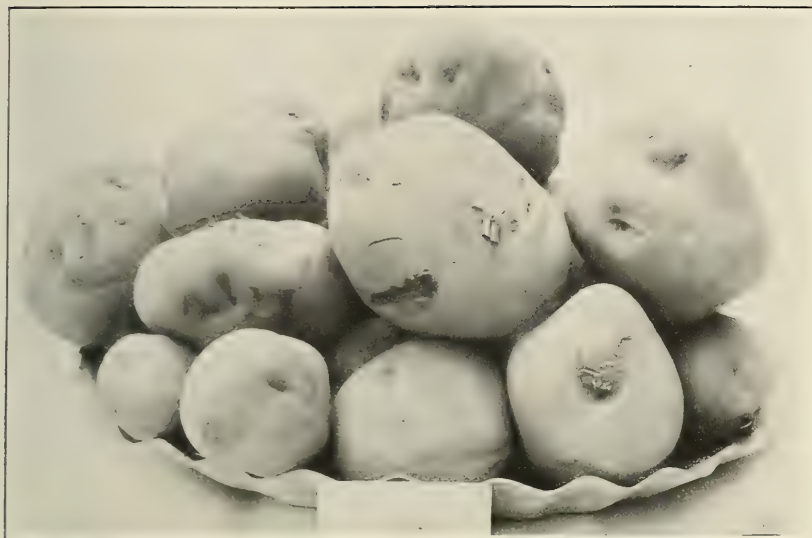
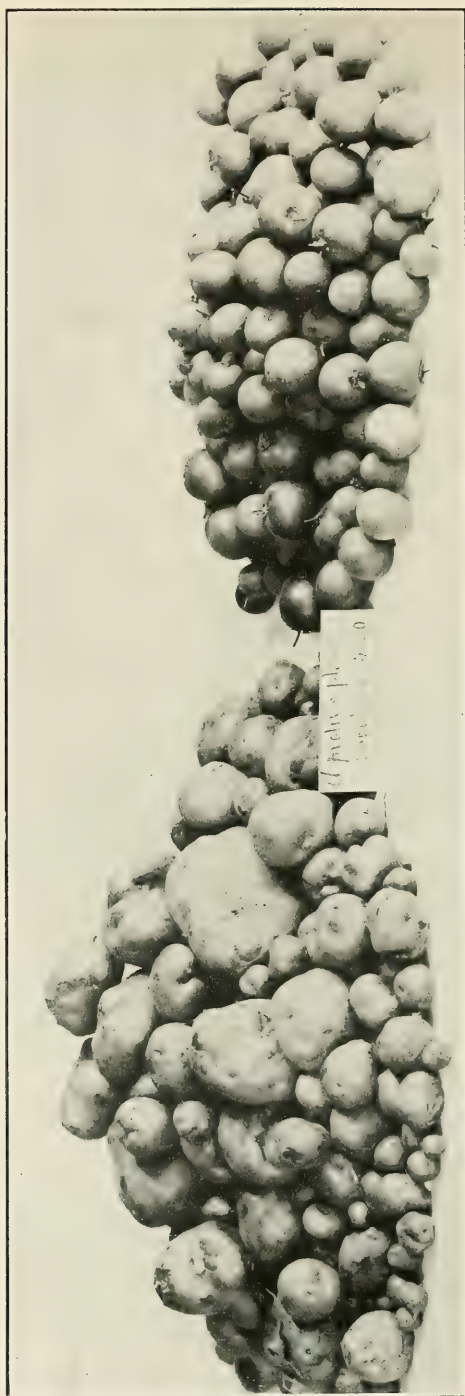


FIG. 1.—AN EXTRA-PROMISING FIRST-YEAR SEEDLING, CROP OF 1910; 24 TUBERS.



FIG. 2.—A PROLIFIC AND FAIRLY PROMISING FIRST-YEAR SEEDLING, CROP OF 1910;
112 TUBERS.



A VERY PROLIFIC SEEDLING PLANT, CROP OF 1911; 244 TUBERS, WEIGHING 6 POUNDS 7 OUNCES, AND 213 SEED BALLS, WEIGHING 2 POUNDS 11 OUNCES.

number of tuber-bearing plants, less than 13 per seed ball. On the other hand, Keeper, which gave only 13.9 per cent of successes, produced an average of 41.5 tuber-bearing plants per seed ball. As both of these pollen parents are known to produce an abundance of viable pollen, it would seem as if a greater affinity existed between Keeper and Up-to-Date than between Irish Seedling and Up-to-Date. In the case of Factor, a total of 74 hand-pollinated flowers, with pollen from 9 varieties, 1 of which was Keeper, produced but 1 seed ball, and that was devoid of seed.

It is apparent from these data that the Up-to-Date class of plants are, as a rule, poor seed bearers. Frequent examination of the flowers of both Factor and Up-to-Date failed to disclose at any time the presence of viable pollen. To all intents and purposes, varieties of this class may be considered as belonging to the male sterility group, and in consequence thereof they can not be successfully employed as pollen parents.

POTATO CROSSES MADE IN 1910.

In 1910 a few crosses were made by W. V. Shear and the writer between several varieties of potatoes growing on the Potomac Flats, Washington, D. C. The success of some of these crosses was so striking that it seems desirable to mention them in the present discussion. The specific crosses to which attention is called are those numbered 8708, 8709, and 8718, the data concerning them being presented in Table III.

TABLE III.—Results of potato crosses Nos. 8708, 8709, and 8718, made on the Potomac Flats, Washington, D. C., in 1910.

Field notes.						Laboratory notes.			
Number of cross.	Parentage of cross.	Date emasculated.	Date pollinated.	Number of flowers crossed.	Number of seed balls developed.	Seed ball.		Number of plants potted.	Percentage of seeds germinated.
						No.	Number of seeds.		
8708	Irish Cobbler × Irish Seedling.....	July 28	July 30	6	6	<i>a</i>	133	105	78.9
						<i>b</i>	108	86	79.6
						<i>c</i>	169	136	85.0
						<i>d</i>	57	47	82.5
						<i>e</i>	256	221	86.3
						<i>f</i>	250	176	70.4
	Total.....						964	771	80
8709	Irish Cobbler × Irish Seedling.....	July 28	July 30	7	5	<i>a</i>	289	264	91.3
						<i>b</i>	200	155	77.5
						<i>c</i>	192	166	86.5
						<i>d</i>	169	121	71.6
						<i>e</i>	134	116	86.6
	Total.....						984	822	83.5
8718	Eureka × Keeper.....	July 28	July 30	7	5	<i>a</i>	256	189	73.8
						<i>b</i>	297	238	80.1
						<i>c</i>	167	122	73.1
						<i>d</i>	189	159	84.1
						<i>e</i>	245	196	80
	Total.....						1,154	904	78.3

The 6 seed balls from cross 8708, Irish Cobbler $\times$ Irish Seedling, in which but 6 flowers were pollinated, produced a total of 964 seeds, or an average of 160.7 seeds per berry. The number of seeds in each berry varied from 57 in seed ball *d* to 256 in seed ball *e*. A fair degree of uniformity in the percentage of germination is to be noted.

The cross 8709, Irish Cobbler $\times$ Irish Seedling, resulted in 5 seed balls from 7 flowers pollinated, and these developed 984 seeds, or an average of 196.8 seeds per berry. The number of seeds from the individual seed balls ranged from 134 to 289 and the percentage of germination from 71.6 to 91.3.

In the third cross, 8718, Eureka $\times$ Keeper, 5 seed balls resulted from 7 flowers pollinated, and these produced 1,154 seeds, or an average of 230.8 seeds per berry, the percentage of germination varying from 73.1 to 84.1.

The highest number of seeds from an individual seed ball was from 8718-*b*, which produced 297 seeds. Another point of interest in these crosses which has not as yet been emphasized is that the seed balls were produced in each case on the same cyme or flower cluster. It is generally believed by potato breeders that the raising of more than one or two seed balls in a cluster is undesirable. On this point East ¹ says:

It is also desirable to stimulate the growth activity in the flower stalk by pollinating four or five flowers on one cyme; then after the berries are partially developed, pinch off the poorest and allow only two to develop to maturity.

In a more recent publication ² East states that the propriety of this procedure is doubtful.

In view of the data which have just been presented it does not appear that the development of seed was curtailed in the slightest, with the possible exception of 8708-*d*, or that the germination was impaired, at least not so far as any data are available to refute it. It is true that the germination as a whole is not high for solanaceous seeds; yet if we take into consideration the fact that every seed removed from the seed ball was counted and that the number of seedlings given is the actual number that reached the potting stage, the showing made should be considered very satisfactory.

METHOD OF GROWING AND TESTING SEEDLINGS.

In order to insure a good development during the first season it is rather essential that the seedling should be allowed a long growing period. To do this it is necessary to start the seeds in a greenhouse or in a hotbed. In the latitude of Washington, in order to insure stocky plants in 3-inch pots, ready to be transferred to the field early

¹ East, E. M. Technique of hybridizing the potato. *In* Proc. Soc. Hort. Sci., 1907, p. 35-40, 1908. (See p. 39.)

² East, E. M. Some essential points in potato breeding. Conn. Agr. Exp. Sta., 31st and 32d Rpt. (1907-08), p. 429-447, pl. 41, 1908. (See p. 441.)

in May, it is desirable to sow the seed in the greenhouse about March 20 to 25. (Pl. V.) The plants are usually spaced in the field in rows 3 feet apart and are set $2\frac{1}{2}$ feet apart in the row. (Pl. VI, fig. 1.) In the ensuing year the tubers are spaced 18 inches apart in the row. (Pl. VI, fig. 2, and Pl. VII, fig. 1.)

The method which has been pursued in determining the merits of the seedlings which have been grown by the Department of Agriculture since 1910, some 60,000 in all, has been rather more comprehensive than is considered advisable from a commercial standpoint. Out of some 28,000 seedlings grown in 1910, nearly 19,000 developed tubers; most of the remaining 9,000 either failed to grow after being transferred from the greenhouse to the open ground or else they failed to produce tubers. All of those which developed tubers were saved, described, and grown in 1911. At harvest time all were again saved for further study and description. This entailed a large amount of work and the recording of many data. Some idea of the way in which these studies were performed may be secured from Plate VII, figure 2. The object in taking so many data and in growing a large number of seedlings which would ordinarily be discarded was to note whether any change occurred in the seedling in the second and subsequent generations. In other words, it was thought desirable to determine whether one might safely discard all unpromising looking seedlings the first season. The results secured indicate that there is little likelihood that a first-year seedling producing pronged, irregular-shaped tubers similar to those in Plate VIII, figures 1 and 2, will ever develop into a smooth-tubered variety. It is also equally apparent that a deep red or blue skinned seedling is never likely to become a desirable commercial variety. On the other hand, the hybridist is not always justified in discarding a seedling which has produced only two or three small tubers, weighing in the aggregate possibly not over 1 ounce, provided the tubers are smooth, shapely, and white skinned. (Pl. VIII, fig. 3). It is an easy matter, however, to decide on the advisability of retaining such seedlings as those shown in Plate IX. Occasionally a seedling is found that is unusually prolific in both tubers and seed balls; such a potato is shown in Plate X.

The data secured from the 1910 and 1911 seedlings have served to make it possible to discard first-year seedlings rather freely, with a fair degree of reliance, it is believed, both with respect to those discarded and those retained.

These seedlings were tested in 1913 and 1914 at three rather widely separated points—Houlton, Me., 1913; Caribou, Me., 1914; Honeoye Falls, N. Y., and Jerome, Idaho. Of the 35,000 seedling plants grown in 1910 and 1911, there now remain less than 150 numbers at the first two points and about 120 at the last point. Since 1911 the practice

has been to discard all those which show undesirable traits, such as straggly or weak vine growth, susceptibility to fungous diseases of either vine or tuber, deep eyes, imperfect shape or color of skin, poor yield, lack of uniformity in size or type, and poor quality. Among those which now remain there appear to be a number of very promising varieties, three of which are shown in Plates XI, XII, and XIII.

SEEDLING INHERITANCE IN THE F_1 GENERATION.

The study of these seedlings both in the laboratory and in the field has furnished an excellent opportunity for observing the inheritance of parental characters. It has been a source of considerable surprise to the writer to find in a class of plants of the cultivated varieties of *Solanum tuberosum* L., which do not normally reproduce true from seeds, such a preponderance of the seedlings showing marked resemblances to either one or the other of the parents. These resemblances have been sufficiently marked in the case of both vines and tubers to permit those familiar with the parental characters to recognize the parentage of a group of seedlings, either in the field or in the laboratory, simply by the preponderance of certain characters peculiar to one or the other of the parents.

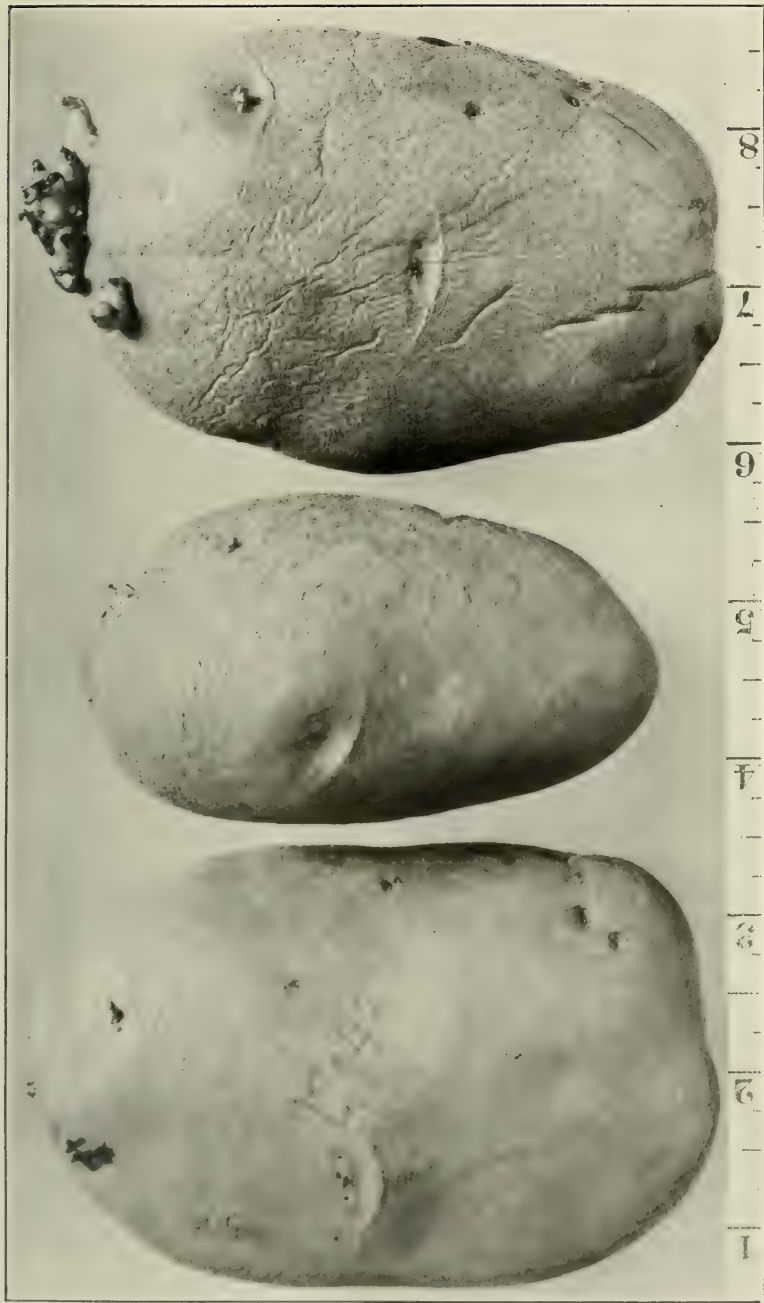
Some rather interesting data have been obtained relative to color inheritance in the tubers. Comparatively recent studies by Salaman¹ on color inheritance in the potato seem to warrant the deduction that a white skin is a recessive character. In this connection the statement is made that a white skin denotes the absence of a color pigment or of a factor necessary to color expression. Salaman found that when certain white-skinned varieties were selfed, their seedlings were all white skinned.

TABLE IV.—Color inheritance in tubers of F_1 seedlings of 1910 crosses, season of 1911.

Parentage of crosses.	Number of seedlings.								Tubers.	
	Total.	White to cream yellow.	Russet.	Mottled.	Flesh.	Red.	Purple.	Violet to black.	Without color.*	With color.
Irish Cobbler × McCormick.....	32	16	.....	2	11	3	.....	.....	Per ct. 50.0	Per ct. 50.0
Irish Cobbler × Irish Seedling.....	1,425	982	18	36	229	104	55	1	70.2	29.8
Irish Cobbler × Keeper.....	870	589	17	23	141	98	2	.....	69.7	30.3
Irish Cobbler × Wild Chilean.....	214	73	.....	72	38	8	12	11	34.1	65.9
Extra Early Eureka × Keeper.....	680	480	.....	91	67	37	5	.....	70.6	29.4
Green Mountain × Keeper.....	88	69	1	11	6	1	.....	.....	79.5	20.5
Gold Coin × Keeper.....	322	257	.....	28	32	5	.....	.....	79.8	20.2
McCormick × Chilean Seedling.....	8	3	.....	4	1	.....	.....	.....	37.5	62.5

*This percentage is based on the number of white to cream yellow and russet tubers.

¹ Salaman, R. N. The inheritance of color and other characters in the potato. *In Jour. Genetics*, v. 1, no. 1, p. 7-46, 29 pl., 1910. (See p. 30.)



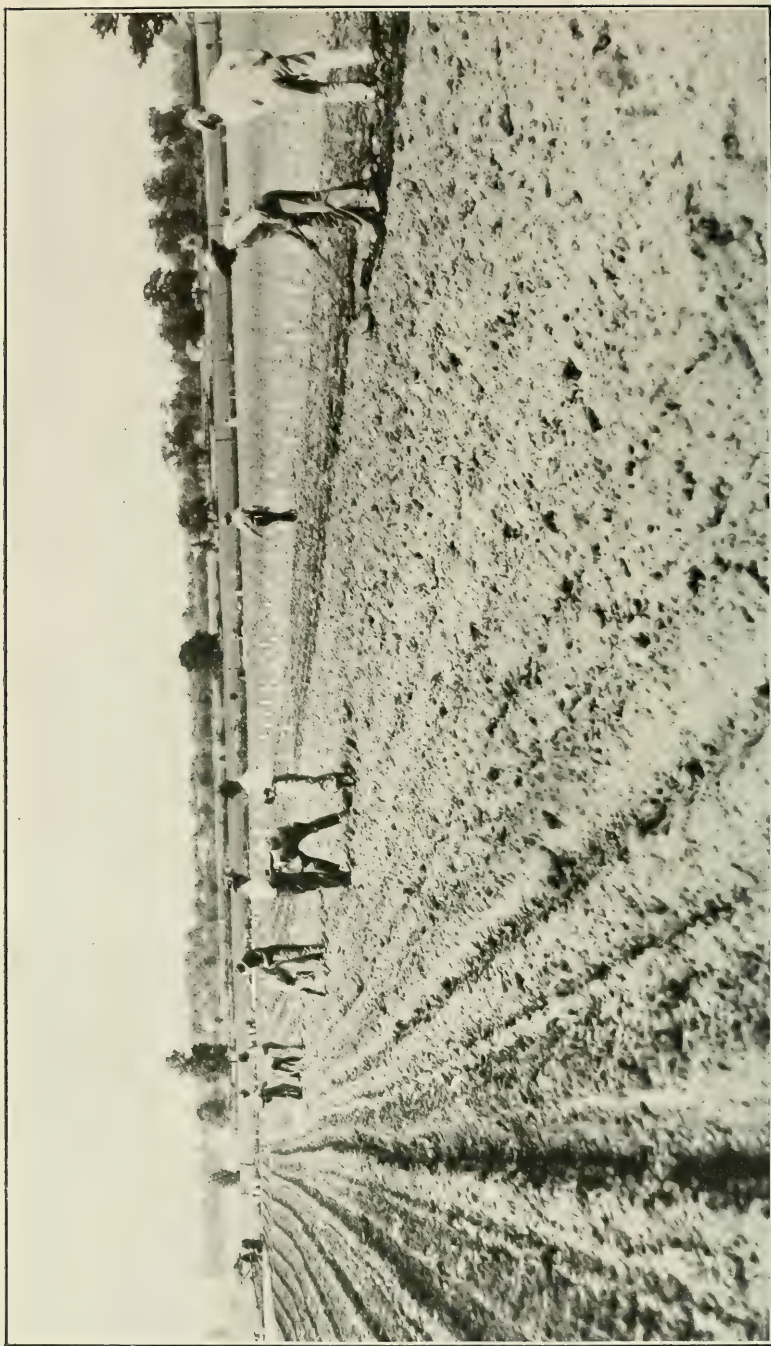
A PROMISING 4-YEAR-OLD SEEDLING OF EARLY EXCELSIOR X APOLLO.



ANOTHER PROMISING 4-YEAR-OLD SEEDLING OF EARLY EXCELSIOR X APOLLO.



A PROMISING 4-YEAR-OLD SEEDLING OF EMPIRE STATE X KEEPER.



PLANTING A POTATO VARIETY COLLECTION ON THE TUBER-UNIT BASIS AT HONEOYE FALLS, N. Y., IN 1911.

The results secured from our own studies as presented in Table IV are not entirely in accord with Salaman's deductions. For example, in a population of 1,425 seedlings from a cross between Irish Cobbler and Irish Seedling, the first parent having a creamy white skin and purplish tinged sprouts and the latter with flesh-tinted skin and purplish sprouts, color was absent in 70.2 per cent of the tubers. Of those showing color, 36 were mottled with white, 229 were flesh, 104 were red, 55 were purple, and 1 was violet-black. In another instance, out of a population of 870 seedlings of Irish Cobbler crossed with Keeper, color was absent in 69.7 per cent of the tubers. The pollen parent, Keeper, being a red-skinned variety, it would seem that if white were recessive a larger proportion of the F_1 generation should have shown color. Almost identical figures were secured when Extra Early Eureka and Keeper were crossed. In this case, in a population of 680, color was absent in 70.6 per cent, or a difference of but nine-tenths of 1 per cent between the two crosses. In view of the fact that the writer regards Irish Cobbler and Extra Early Eureka as one and the same variety, the parentage of the two crosses is thus identical. When it is considered that the data for the two crosses were secured and tabulated independently of each other, the uniformity of the data is all the more remarkable. When the Irish Cobbler is crossed with a Chilean seedling, a different set of data is obtained. In a population of 214, only 34.1 per cent of the tubers were free from color.

When white-skinned and white-sprouted varieties were crossed with red-skinned varieties, the proportion of white-skinned seedlings was larger, as is shown in the following crosses: Green Mountain $\times$ Keeper produced 88 seedlings, of which 79.5 per cent were devoid of color; of those which did show color, 11 were mottled, 6 flesh, 1 russet, and 1 red. Gold Coin $\times$ Keeper produced 322 seedlings, of which 79.8 per cent were devoid of color; and of those which showed color 28 were mottled, 32 were flesh, and 5 were red. The remarkable similarity of color expression of these two crosses is again accounted for by the fact that the varieties Green Mountain and Gold Coin are regarded as identical or so nearly so as to be practically indistinguishable from each other.

While numerous other examples might be cited, it is believed that sufficient data have been presented to justify the assertion that white is not a recessive character in the seedlings of the crosses just named.

POTATO IMPROVEMENT BY SELECTION.

The improvement of the potato by selection alone restricts the operator to such variations as may occur within the variety. Fortunately, this field of endeavor is not such a limited one as it might at first appear to a layman, since considerable variation already exists

within most of our cultivated varieties. This is particularly true with respect to uniformity in shape and size. In addition to this, it is well known to all observant potato growers that there is a great variation in the number of tubers produced by individual plants. Some plants produce 2 or 3 large tubers, with no small ones; others the same number of large tubers, but with a half dozen or more small ones; while others may be found producing from 6 to 10 or more medium-sized merchantable tubers and practically no small ones. It is clearly evident that the latter plant is the most desirable, provided that it has the power of reproducing this character. Probably very few plants have a productive capacity in excess of the average optimum expression of the variety. The abnormal yield is generally due to one or more of several causes, such as a larger or more vigorous seed piece, a slightly greater supply of plant food or moisture, or both, minimum injury from insect pests and fungous diseases, or any other favorable condition which enables that particular plant to reach or exceed the optimum or normal production of the variety. Failure to take these factors into consideration may lead the selectionist to interpret his results erroneously or to be unduly elated or depressed over the behavior of his selections in the first and second years of their isolation.

In addition to productiveness and uniformity in shape and size, there may be still other qualities which it is possible to secure through intelligent selection. Some of the more important of these qualities are as follows:

- (1) Disease resistance of vine.
- (2) Drought resistance of vine.
- (3) Heat resistance of vine.
- (4) Vigor of plant.
- (5) Greater adaptability to peculiar environmental conditions of soil or climate.

Undoubtedly other objects of selection could be mentioned, such as tubers with shallower or less numerous eyes; but the foregoing may suffice to show the possibilities for selective work in the improvement of the potato. That the subject is not a new one and that its possibilities have not been unrecognized by earlier investigators is self-evident from the few examples which are cited on the following pages.

EARLY SELECTION EXPERIMENTS.

One of the earliest recorded experiments in which a definite effort was put forth to increase the productive capacity of the potato plant was that carried on from 1868 to 1882 by Hallet,¹ who reports as follows:

In the case of the potato, I have also applied my system, starting every year with a single tuber, the best of the year (proved to have been so by its having been found to

¹ Hallet, F. P. Food-plant improvement. *In Nature*, v. 26, no. 656, p. 91-94, 1882. (See p. 92.)

produce the best plant) for now fourteen years. My main object here has been absolute freedom from disease, and these potatoes are now descended from a line of single tubers, each the best plant of the year and absolutely healthy; and concurrently with the endeavor to wipe out all hereditary tendency to disease, I have always kept in full view the point of increasing productiveness. The result may be thus shortly stated: Dividing the first twelve years into three periods, the average number of tubers upon the annual best plant selected was, for the first period of four years, 16; for the second period of four years, 19; for the last period of four years, 27; or nearly double the number produced during the first series of four years. And if, as I might very fairly have done, I had confined the first period to the first three years (instead of four), the last period would have shown an average of 27 tubers against 13 in the first period, or more than double.

The care with which this experiment was apparently conducted and the selection of the strongest, most disease-free, and productive plants would seem to indicate that Hallet, at least, had a very clear conception of the advantages of selection in building up vigorous and productive strains of potatoes.

Carrière says:¹

The potato furnished us with examples of modifications just as remarkable as those which we have reported for beans and for corn. . . . Every year, in reality, when we harvest the tubers and wish to conserve the purity of the variety, we are obliged to purify, that is to make a choice and reject those which, as we say, have degenerated. . . . The modifications in the potato may occur equally well in the underground parts; that is what has happened in the variety called Pousse-debout. The name Pousse-debout has been given to this variety because the tubers which it produces, instead of being placed flat, or nearly so, in the soil, are arranged one against the other, much like pieces of wood are disposed for transformation into charcoal.

It is further stated that the Marjolin potato is a variety possessing the peculiar quality of never flowering and of being very early, but notwithstanding this fact it is continually producing plants which flower and produce seed, and which, owing to this fact, are not as early as the parent plant. In yet another variety, the Chardon, Carrière observed transformations in color of flowers, shape of tubers, and season of ripening, and this, too, in a strain which had been under observation for a long time without having previously shown any variation whatsoever.

Goff's² experiments in 1884 and 1885 demonstrated that tubers from productive plants gave larger yields than tubers from unproductive plants, the total gain being a little more than 24 per cent.

In 1897 Fischer³ began some selection work with the potato, in which variations in productiveness, shape, and starch content of

¹ Carrière, E. A. *Production et Fixation des Variétés dans les Végétaux*, 72 p., illus. Paris, 1865. (See p. 40-41.)

² Goff, E. S. *Experiments with tubers taken from productive and unproductive hills*. N. Y. (Geneva) Agr. Exp. Sta., 3d Ann. Rpt., 1884, p. 301-305, Albany, 1885; 4th Ann. Rpt., 1885, p. 232-235, Albany, 1886. (A copy of this 4th Rpt. was published also at Rochester. In this copy the reference will be found on p. 204-207.)

³ Fischer, Max. *Kartoffelzüchtungs- und Anbauversuche*. In *Föhlings Landw. Ztg.*, Jahrg. 49, 1900, Heft 8, p. 301-307; Heft 9, p. 343-352; Heft 10, p. 369-372.

tuber, and also in the growth habit of the vine, were studied. The work of Fischer was very largely carried on in pots, under as nearly uniform conditions as it was possible to obtain, and yet the variations in the yield of tubers were in some instances in the ratio of 100 to 233.3.

The individual deviation within the variety itself was found in the case of the Saxon onion potato to be associated with certain definite characters; for example, flat-round tubers rich in starch were found to be correlated with a more or less restricted vegetative growth and tuber yield. Long tubers poor in starch were, on the other hand, found to be correlated with strong vegetative growth and a high tuber yield as compared with that of the flat-round ones. This is strikingly shown in the following data, which give the relative proportion of dry stalks and tubers from the two types of mother tubers:

I. Flat-round mother tubers rich in starch (18.68 per cent); dry stalks, 100; tuber yield, 100.

VII. Long mother tubers poor in starch (11.83 per cent); dry stalks, 141.5; tuber yield, 204.

The deviations within these types were also noted by Fischer, and data were presented (Table V), a study of which shows that, while considerable deviation existed within the two types, the maximum yield of the flat-round tubers rich in starch did not approach very closely either in weight of dry stalks or of tubers to that of the lowest yield from the long tubers poor in starch.

TABLE V.—*Individual deviations in the development of vine and tuber within the same strain of a variety.*¹

Strain No.	Character of strain.	Dry stalks.	Tuber yield.	Average gain of long over flat-round tubers.	
				Dry stalks.	Tubers.
II	Flat-round tubers rich in starch.....	<i>Per cent.</i> 100	<i>Per cent.</i> 100	<i>Per cent.</i>	<i>Per cent.</i>
III	do.....	114.5	167	-----	-----
V	Long tubers poor in starch.....	142	216.7	48	62.5
VI	do.....	175.5	233.3		

¹ Table compiled from Fischer, Max. Op. cit., p. 305.

Fischer also noted that the plants from the flat-round tubers were shorter jointed and matured earlier than those from the long tubers. This would indicate that the latter represented a later maturing strain.

In December, 1904, Eustace¹ reported the result of a season's study on "Productive vs. unproductive hills." The method of selection pursued by Eustace was as follows: At harvest time in the

¹ Eustace, H. J. An experiment on the selection of "seed" potatoes: Productive vs. unproductive hills. *In Proc. Soc. Hort. Sci.*, 1903-4, p. 60-62, 1905.

fall of 1903 a field of potatoes was selected the variety of which was known to be pure, and in a place where the soil was uniform 100 consecutive hills were dug and weighed separately. From these 100 hills the 25 heaviest and 25 lightest yielding hills were selected. This process was repeated until 125 hills of each had been secured. In the following spring 10 rows of 232 plants each were planted from the heaviest yielding hills and 5 from the light-yielding ones. The resultant yields averaged $362\frac{1}{4}$ bushels per acre from the productive hills and $339\frac{1}{8}$ bushels from the unproductive, the gain in favor of seed from the heaviest yielding hills being at the rate of $23\frac{1}{2}$ bushels of marketable tubers per acre.

It was found that the amount of variation in the yields of adjacent hills in the 1904 crop was almost as great as in that of the original stock. The 1904 variations were 11.9 ounces, or 39.18 per cent, as against 9.37 ounces, or 39.44 per cent, in the 1903 crop. In this connection Eustace says:

That the variation was not materially reduced by the uniform conditions under which the experiment was made was a surprise. The conclusion is that factors which are apparently unimportant produce wide differences in yield.

From our present knowledge of the behavior of individual hills of potatoes, it seems quite certain that Eustace would have secured much more uniform results had the progeny of each individual hill been planted separately. In mass plantings individual variations are obscured, rather than emphasized, as in the tuber-unit or progeny-row method.

At the annual meeting of the American Breeders' Association, in 1907, Waid¹ reported the results of studies which he had undertaken at the Ohio Agricultural Experiment Station, in which the progeny from productive and unproductive plants in 1903 had been carefully studied during 1904, 1905, and 1906. The results of this work showed quite clearly that with few exceptions low-yielding plants remained unproductive.

The 3-year average from high and low yielding plants was found to be 1.38 pounds for the former and 0.73 pound for the latter, or a difference of over 89 per cent. A comparison of yields from the productive plants and plants from common stock showed a gain of over 25 per cent for the former.

A further study of Waid's data reveals the fact that the average weight of the 10 original high-yielding hill selections was 2.38 pounds per plant, whereas the 3-year average of their progeny was only 1.38 pounds per plant. This suggests that in the selection of high-yielding hills one is not at all certain what proportion of the hills is likely to maintain their seemingly productive character.

¹Waid, C. W. Results of hill selection of seed potatoes. In Amer. Breeders' Assoc., 3d Ann. Rpt., 1907, p. 191-198.

In this connection East¹ suggests the possibility that Waid's results may have been influenced by the following factors: (1) The size of the seed pieces, and (2) since Waid apparently used a commercial stock, he was not absolutely certain that he was dealing with a single variety, or, in other words, with a pure strain. This latter fact East thinks may account for differences in the results secured by Waid in the second and third seasons. He is inclined to believe that the differences were purely physiological phenomena of development, entirely separate from questions of inheritance.

On page 131 of the report just cited East gives his experience with high and normal yielding hills selected from a select strain of Rural New Yorker No. 2. His statement with respect to this work is as follows:

In 1906 we had in stock a supply of the well-known variety Rural New Yorker No. 2, which had been grown from a single hill in 1904. A selection of tubers from the five best yielding hills was planted in 1907 and compared with five normal hills producing only one-half as much. The five best yielding hills averaged 1,200 grams (2 pounds 10 ounces) of tubers per hill, with an average set of eight tubers. The check hills averaged 600 grams, with a set of four tubers each. Ten hills were planted in each case, two tubers being planted from each hill. In every case pieces of about the same weight were planted. The yield from the high-yielding selections was at the rate of 101 bushels per acre, while the yield from the check hills was at the rate of 128 bushels per acre.

In 1908 the progeny from the high-yielding strain averaged 96 bushels per acre and that from the check 90 bushels. In 1909 the yields were, respectively, 115 and 120 bushels per acre. The average yield for the three seasons was at the rate of 104 bushels per acre from the high-yielding and 113 bushels per acre from the check lot. In view of these facts, East believes that great caution should be exercised in recommending asexual selection as a means of increasing the yield or improving the variety. He further states that of the many investigations reported none have furnished indisputable evidence of improvement.

In a more recent article Berthault² has published the results of a rather exhaustive study of the potato. The portions of Berthault's studies with which the present article is concerned are those relating to the hereditary transmission of characters, variations through asexual and germinal reproduction, and the normal variations within the variety itself.

On page 49, Berthault summarizes his observations upon asexual reproduction, which, roughly translated, are as follows:

- (1) That the form of the tuber is not a stable character in our cultivated varieties.
- (2) That the color, generally maintained through asexual propagation, sometimes varies.

¹ East, E. M. The transmission of variations in the potato in asexual reproduction. *In* Conn. Agr. Exp. Sta. 33d and 34th Rpt. (1909-1910), p. 119-160, 1910. (See p. 130-131.)

² Berthault, Pierre. Recherches botaniques sur les variétés cultivées du *Solanum tuberosum* . . . *Ann. Sci. Agron.*, s. 3, ann. 6, t. 2, 1911, no. 1, p. 1-59; no. 2, p. 87-143; no. 3, p. 173-216; no. 4, p. 248-309.

(3) That the depth of the eyes, a character almost always maintained in asexual reproduction, also offers, without apparent cause, examples of bud variation.

SELECTION METHODS.

TUBER-UNIT METHOD OF SELECTION.

A method advocated by Webber,¹ known as the tuber-unit method of selection, has recently received considerable attention. This method consists in planting select tubers of a variety in such a way that the plants from each tuber will be definitely isolated from each of the other tuber units. The tuber is cut longitudinally through its axis into four as nearly equal parts as possible, aiming in all cases to cut through the cluster of eyes surrounding the terminal one. The quarters are planted consecutively, and a double space is left between the four units of each tuber in order that they may be more easily distinguished from one another. When the plants have reached their full development, each unit should be carefully dug and again examined. If it is found that some of the marked units produce a uniform lot of tubers, both as to shape and size, and are equal to or more productive than the general average of the variety, they should be saved for further trial. By this method it is claimed that not only can uniformity in size and shape be secured but the productiveness of the variety may be increased, because of the fact that selection tends to weed out all of the unproductive plants. By continuing this line of work one may finally secure an excellent commercial strain of potatoes.

HILL SELECTION.

Another method, varying slightly from the one first described, consists in making individual hill selections in the potato field at digging time. The particular qualities sought after are practically the same, viz, greater uniformity in size and shape and a maximum number of merchantable tubers. The selected hills are kept separate. Each should be given a number and should be sufficiently described to permit further comparison when the progeny is harvested. It will be found that many a promising first-year selection will bring disappointment in the second season. A few, however, will maintain their superiority, and these should be saved and propagated.

This line of work has proved almost as fascinating to the writer as the broader one of combining desirable characters through cross-fertilization or hybridization. It is a field of endeavor open to any wide-awake potato grower and within its limitations offers greater promise of results for the time and effort expended than that of the production of seedling plants.

Cards, the character of which is shown by the accompanying samples, have been prepared by the writer for the purpose of recording

¹ Webber, H. J. Method of improving potatoes. In N. Y. (Cornell) Agr. Exp. Sta., Bul. 251, p. 322-332, 1908.

were remarkably uniform in size and there could, therefore, have been little difference in the size of the seed pieces used. Any variation, therefore, which occurred between the plants of the various tubers which were planted would seem to be due to some inherent tendency in the tuber itself. The remarkable dissimilarity between the growing plants of the individual units of a variety planted contiguously in the row was so surprising that some three dozen units were photographed and when these were harvested the tubers were also photographed. It was found that the divergency in yield was just as great as in the size and vigor of the plants. In 1912 five units were planted from both the strong and the weak plants, and it was found in practically every instance that the low-yielding 1911 plants gave poor germination, a feeble vine growth, and a still lower yield than in 1912 (Pl. XV). Table VI gives the data obtained during 1911 and 1912 from 12 strong and weak tuber-unit plants of well-known commercial varieties.

TABLE VI.—*Potato yields from strong and weak tuber-unit plants in 1911 and 1912.*

[Weight of tuber yields in pounds.]

Accession No.	Variety.	Strong plants, 1911.			Strong plants, 1912.			Weak plants, 1911.			Weak plants, 1912.		
		Primes.	Culls.	Total.	Primes.	Culls.	Total.	Primes.	Culls.	Total.	Primes.	Culls.	Total.
4245	Beauty of Hebron.....	4.0	1.5	5.5	2.9	1.2	4.1	0.4	0.9	1.3	0.7	1.0	1.7
4235	Carman No. 1.....	2.6	1.6	4.2	4.4	.8	5.2	.....	.8	.8	.....	.14	.14
4972	Gold Coin.....	3.4	2.0	5.4	3.0	.54	3.54	.....	1.1	1.1	.4	.25	.65
4968	Green Mountain.....	3.8	1.3	5.1	2.0	.6	2.6	.....	1.1	1.1	.14	.17	.31
8686	do.....	4.3	.3	4.6	4.8	.9	5.7	.....	.8	.8	.....	.04	.04
4970	Irish Cobbler.....	3.8	.3	4.1	1.7	2.0	3.7	.9	1.0	1.9	.25	.38	.63
5036	Keeper.....	2.6	2.0	4.6	2.9	.85	3.75	.....	.6	.6	.....	.02	.02
6153	McCormick.....	2.8	1.3	4.1	2.1	.4	2.5	1.5	.3	1.8	.12	.29	.41
5460	Norcross.....	3.9	1.4	5.3	3.94	1.1	5.04	.....	.5	.5	.....	.03	.03
5462	do.....	4.4	1.4	5.8	4.1	1.7	5.8	.....	.9	.9	.12	.08	.2
5480	Rural Blush.....	1.5	2.7	4.2	3.9	.64	4.54	.....	1.3	1.5	.04	.33	.37
6690	Twentieth Century.....	3.1	1.0	4.1	2.7	.64	3.34	.....	.1	.1	.....	.....	.....
	Total.....	40.2	16.8	57.0	38.44	11.37	49.81	3.0	9.4	12.4	1.77	2.73	4.50
	Average.....	3.35	1.4	4.75	3.2	.95	4.15	.25	.78	1.03	.15	.23	.38

Two-year tuber-unit average:

Strong plants—3.23 pounds primes; 1.18 pounds culls; total, 4.46 pounds.

Weak plants—0.20 pound primes; 0.51 pound culls; total, 0.71 pound.

Gain in primes in favor of strong plants, 1,540 per cent; total gain in favor of strong plants, 528.2 per cent.

The average yield of merchantable or prime tubers from the strong plants was 3.35 pounds in 1911, with 1.4 pounds of culls, while the yield from the weak plants was 0.25 and 0.78 pound, respectively. In 1912 the yields were 3.2 pounds of primes and 0.95 pound of culls from the strong plants and 0.15 and 0.23 pound, respectively, from the weak plants. The average production for 1911 and 1912 was 3.28 pounds of primes and 1.18 pounds of culls from the strong plants and 0.20 pound of primes and 0.51 pound of culls from the weak plants. These yields represent a gain in primes of over 1,500 per cent in favor of

the strong plants and a total gain of over 500 per cent. The graphic chart shown in figure 1 illustrates quite clearly the marked differences in vine and tuber production. It would be misleading to leave the

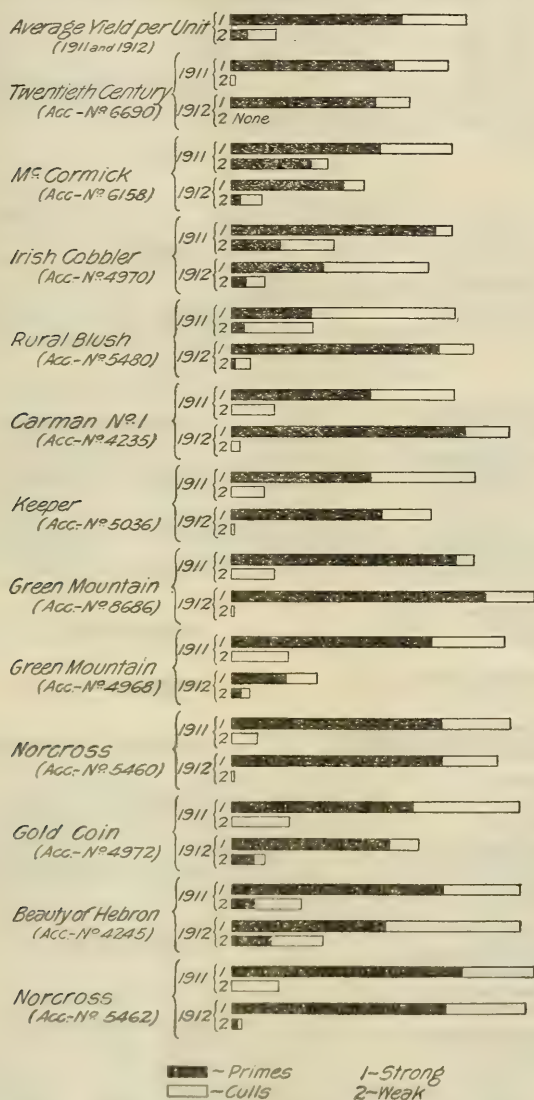


FIG. 1.—Diagram showing the relative yields between strong and weak tuber-unit plants at Honeoye Falls, N. Y., in 1911 and 1912.

impression that these data represent the gains that are likely to accrue through selection. The lesson that these data should convey is that tubers from weak, unproductive, or diseased plants produce similar or even worse progeny and that the greatest benefit derived

from selection work is the weeding out of these undesirable strains. It is not at all unlikely that from 5 to 10 per cent of weak, diseased, or unproductive plants may be found in all unselected seed potatoes. It is also equally certain that in nine cases out of ten in ordinary field

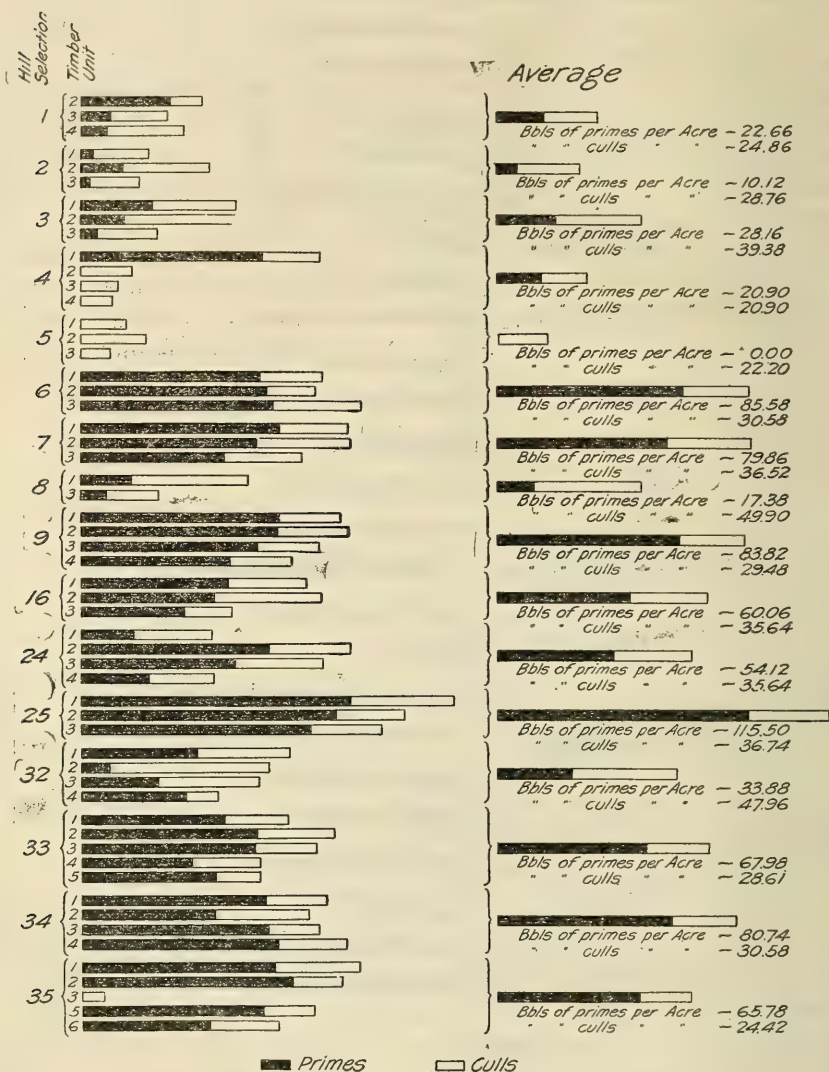


FIG. 2.—Diagram showing the hill-selection performance record, season of 1912.

practice these are unrecognized, because the weak or diseased plants are scattered here and there throughout the field and are obscured by surrounding healthy plants. Their resultant effect on yield is also unnoted and will probably remain so until we demand a practically perfect stand.



FIG. 1.—PROGENY OF THREE TUBER UNITS EACH OF HILL SELECTIONS NOS. 2 AND 25. The upper cut shows the progeny of selection No. 2, the center one that of No. 25, and the lower cut the combined progeny of No. 25 on the left and of No. 2 on the right.



FIG. 2.—VARIATION IN YIELD BETWEEN TUBER UNITS FROM THE SAME HILL. The upper cut shows the progeny of two tubers from hill selection No. 35; the lower cut that from hill selection No. 4.

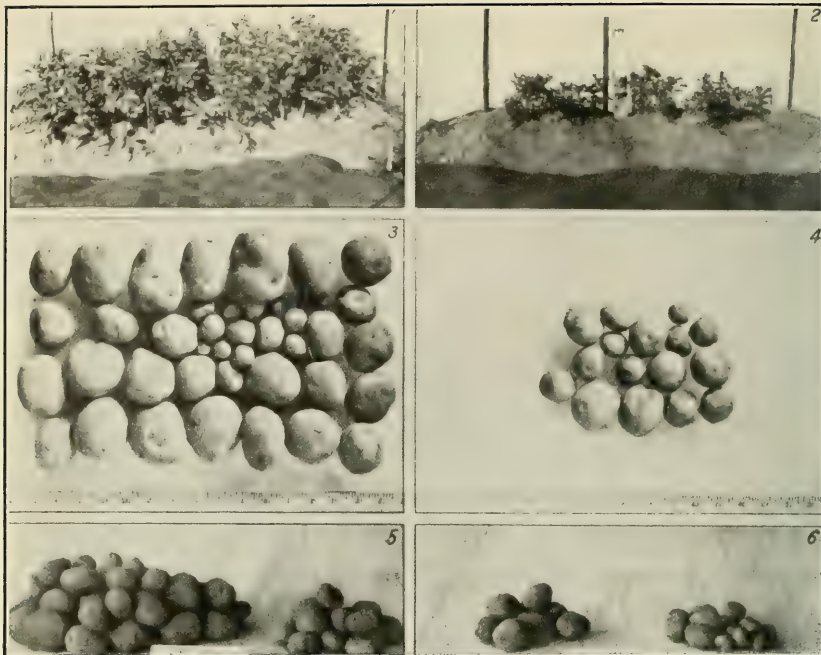


FIG. 1.—STRONG AND WEAK TUBER UNITS OF THE GOLD COIN VARIETY OF POTATOES.

Nos. 1 and 2 represent strong and weak tuber units in 1911; Nos. 3 and 4 represent yields from tuber units 1 and 2; Nos. 5 and 6 represent yields in 1912 from five tuber units of Nos. 3 and 4.



FIG. 2.—STRONG AND WEAK TUBER UNITS OF THE RURAL BLUSH VARIETY OF POTATOES.

No. 1 represents a strong tuber unit in 1911, with its 1911 yield and the 1912 yield from five of its tuber units. No. 2 represents a weak tuber unit in 1911, with its 1911 yield and the 1912 yield from five of its tuber units.

HILL-SELECTION STUDIES.

In June, 1911, the writer, through the courtesy of a potato grower near Portsmouth, Va., was enabled to make some hill selections in a field of Irish Cobblers. These selections were made with two objects in view: (1) To increase the yield and (2) to determine the feasibility of carrying over the first-crop seed for the next season's planting. Unfortunately, the results of this work were practically eliminated by a severe freeze in April, 1913, which cut the young shoots to the ground, killing many of them outright. The 1912 crop was so promising, however, that it seems worthy of mention. The 1911 selections were all planted on the tuber-unit basis. Plate XVI and figure 2 show the results secured from some of the more promising. Of the 16 selections shown in figure 2, Nos. 6, 7, 9, 25, and 34 are the most promising, and among these No. 25 is far superior to the others. The 1912 yields of the 16 selections, computed on a per acre basis from the average of the units planted of each selection, are as follows:

Selection No. 1, 3 units planted, yielded at the rate of 22.7 barrels primes and 24.9 barrels culls.

Selection No. 2, 3 units planted, yielded at the rate of 10.1 barrels primes and 28.8 barrels culls.

Selection No. 3, 3 units planted, yielded at the rate of 28.1 barrels primes and 39.4 barrels culls.

Selection No. 4, 4 units planted, yielded at the rate of 20.9 barrels primes and 20.9 barrels culls.

Selection No. 5, 3 units planted, yielded at the rate of 0 barrel primes and 22.2 barrels culls.

Selection No. 6, 3 units planted, yielded at the rate of 85.7 barrels primes and 30.6 barrels culls.

Selection No. 7, 3 units planted, yielded at the rate of 79.9 barrels primes and 36.5 barrels culls.

Selection No. 8, 2 units planted, yielded at the rate of 17.4 barrels primes and 49.9 barrels culls.

Selection No. 9, 4 units planted, yielded at the rate of 83.8 barrels primes and 29.5 barrels culls.

Selection No. 16, 3 units planted, yielded at the rate of 60.1 barrels primes and 35.6 barrels culls.

Selection No. 24, 4 units planted, yielded at the rate of 54.1 barrels primes and 35.6 barrels culls.

Selection No. 25, 3 units planted, yielded at the rate of 115.5 barrels primes and 36.7 barrels culls.

Selection No. 32, 4 units planted, yielded at the rate of 33.9 barrels primes and 48 barrels culls.

Selection No. 33, 5 units planted, yielded at the rate of 68 barrels primes and 28.6 barrels culls.

Selection No. 34, 4 units planted, yielded at the rate of 80.7 barrels primes and 30.6 barrels culls.

Selection No. 35, 5 units planted, yielded at the rate of 65.8 barrels primes and 24.4 barrels culls.

It is evident from the data presented that other causes than that of inherent unproductiveness must have operated to lower the yield in selections 1 to 5. This fact is made still clearer by the behavior of selection No. 4, in which the first unit gave a reasonably good yield of primes or merchantable tubers, while the remaining ones did not produce any. It is believed that the seed tubers from the 1911 selections were either infected with some obscure disease or happened to have been planted in previously infected soil. All the selections were grown in the same or in contiguous rows, so there is little likelihood that the moisture or plant-food content of the soil was deficient in the one case and not in the other. The behavior of the plants during the growing season strongly corroborated the disease theory and sustains a previous statement in this bulletin in connection with varietal tuber-unit studies, namely, that the chief value of such studies consisted in the elimination of diseased and weakened plants. It would seem probable from the behavior of No. 25 that a strong, vigorous, and productive strain had been isolated. The term "probable" is used advisedly, because, as previously stated, the best selections, including, of course, No. 25, were unfortunately cut to and below the ground by a very severe freeze late in April, 1913. The injury sustained was so severe that very few of the plants survived, and those that did survive made a very unsatisfactory growth and crop. These selections have therefore been lost, and a new start has become necessary.

Thus far, all selections that have been made for disease resistance have proved undesirable, as they either did not retain this quality or else they were unproductive commercially or otherwise. The highest degree of success can only be attained from either the tuber-unit or hill-selection method by working with rather large numbers. It is hardly conceivable that there exist many strains within a variety that are especially productive or commercially desirable, or that are markedly resistant to disease. Occasionally one may be fortunate enough to isolate such a strain with a minimum amount of effort, but the chances are strongly in the opposite direction. This statement is not made for the purpose of discouraging anyone from attempting to improve his seed stock by up-to-date seed-selection methods. The intention is rather to encourage the selectionist to make a larger number of selections and thereby increase his chances of securing a superior strain.

The selection of a large number of high-yielding hills which are then thrown together for mass planting the ensuing year is not likely to result in any marked improvement except by the elimination of the diseased or the unproductive plants. The only certain method of securing a superior strain is to plant each selection separately, as rec-

commended in Circular 113 of the Bureau of Plant Industry and Farmers' Bulletin 533, United States Department of Agriculture.

Every progressive potato grower should have his selection plat, in which to grow his yearly selections; and, in addition, he should have his increase plat, where the promising selections may be increased for the field-crop planting.

SUMMARY.

The data presented seem to justify the following statements:

(1) That the potato crop of the United States is of sufficient economic importance to demand a most careful study of all favorable and unfavorable factors influencing the yield.

(2) That the economic use made of the potato in this country is relatively unimportant when compared to that of Germany.

(3) That deterioration of our cultivated varieties through improper cultural practices and through disease necessitates the improvement of existing varieties through the exercise of greater care in the selection of the seed and through the development of new seedling varieties possessing greater disease resistance or better commercial qualities.

(4) That the term "plant breeding," when applied to the potato, should be construed as sexual rather than asexual reproduction. In other words, it is believed that a distinction should be made between "breeding" and "selection."

(5) That the work of Goodrich as a potato-plant breeder was epoch making, in that it resulted in giving us the progenitor of the world-famous Early Rose.

(6) That while the growing of seedling potatoes may offer greater possibilities than selection alone, the latter method can be practiced with much greater ease than the former. Breeding can be indulged in only by the few, while selection may be engaged in by the many.

(7) That the almost total failure of our present-day commercial varieties to produce seed balls is due to male sterility rather than to imperfect pistils or ovaries.

(8) That the commonly accepted theory regarding the inadvisability of allowing more than one or two seed balls to develop on a cyme, on the assumption that weak seedlings would result, is not substantiated in crosses 8708, 8709, and 8718, which developed five and six seed balls apiece.

(9) That the data secured from some of the crosses indicate very strongly that some varieties are prolific seed bearers, while others are not.

(10) That the tuber-unit and hill-selection methods of seed selection are chiefly valuable in pointing out the weak, unproductive, and diseased seed tubers.

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BULLETIN No. 196

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C.

PROFESSIONAL PAPER

May 29, 1915

METHODS FOLLOWED IN THE
COMMERCIAL CANNING OF FOODS

By

A. W. BITTING

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE



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MODERN FACTORY EQUIPMENT AND METHODS.

METHODS OF STERILIZATION.

Sterilization may be accomplished by heat below, at, or above the boiling temperature, depending upon the length of time the heat is applied and the number of applications made. It is not practicable to sterilize all foods in the same way because of injury to quality or prohibitive expense. Sterilizing below the boiling point is feasible only for a few products, principally fruits, and then is advisable only when it is desired to preserve a very fine appearance. This may be accomplished above 165° F. by maintaining the temperature for a longer time than when boiling, or by repeating the operation on two or more successive days. The object is to prevent breaking the tissue and loss of juices from the fruits by excessive heat. This method of sterilization has been applied experimentally and in private canning with gratifying results, but it involves so much time and labor that it is not used commercially except in a limited way. Sufficient work has not been done to say definitely what products can best be treated in this way nor what temperatures are best suited for different foods. It has been used chiefly with foods in glass, though equally satisfactory results are obtained with foods in tin.

Cooking at boiling temperature is practiced with nearly all fruits, as the germs present are easily destroyed. Most of the fruits are processed for from 12 to 25 minutes.

¹ A revision of Bureau of Chemistry Bulletin 151, enlarging upon certain phases of the manufacturing processes, and incorporating a summary of the results of the experimental work of the season of 1912 and 1913. Since the information includes only the methods of commercial canning, it is of no interest to the home canner. Presentation of the trade practices does not imply an indorsement by the Bureau of Chemistry. Prepared by A. W. Bitting while food technologist of the bureau.

The tomato is the most important vegetable processed at boiling temperature, which is usually maintained for 50 minutes.

Cooking at a temperature above the boiling point is necessary or advantageous for most vegetables, fish, milk, and meats. It is accomplished in retorts where steam is admitted under pressure, in retorts where water can be superheated, or on the open calcium chlorid or oil bath.

Among the vegetables requiring a high temperature in processing are corn, peas, beans, both green and dry, pumpkin, beets, and sweet potatoes. Corn is one of the difficult products to can, requiring a temperature of from 245° to 250° F. for from 75 to 80 minutes, depending to a considerable extent upon how dry it is packed. If very dry, the heat will penetrate to the center of the can very slowly, the actual time required to raise the center to the temperature of the bath being from 55 to 65 minutes. In a can of peas this is accomplished in 6 or 7 minutes, the difference being due to the fact that heat currents are set up in the liquid portion of the peas, while they are absent in the corn. The necessity for a high temperature is therefore dependent upon the ease with which the heat can penetrate the product, as well as the resistance of the organisms. Some products which were formerly processed by boiling for a long time are now given a higher temperature for a few minutes, as the product has a much better appearance when it is not overcooked.

Meat products, as a rule, contain highly resistant organisms, besides which the majority of these foods are of such a consistency that the heat penetrates them very slowly. As a class they require the heaviest process. Milk also contains very resistant germs, but being liquid it heats rapidly; in order to keep it smooth and prevent the portion in contact with the tin from scorching, the cans are turned or agitated almost continuously during the cooking.

DETERMINATION OF TEMPERATURE AND TIME OF PROCESSING.

In sterilizing, the heat must be applied equally to all cans, and it is therefore necessary to deliver steam at the bottom of the kettle, whether open or in a retort, to insure a circulation of the heat. In retorts, whether steam or hot water is used, there must always be a vent open to give off steam in order to hold the heat uniform at all points. The thermometer is the all-important tester, for if it does not show the proper degree of temperature, spoilage will follow. To test the uniformity of temperature in a retort, self-registering thermometers are sealed in a number of cans when placed in the crates, the cans are marked, and when the cooking is completed the thermometers are examined and compared, so that the heat may be adjusted until all give like readings. In a similar manner the time required for the heat to reach the center of the can is obtained, experimental lots being run for varying periods, and the temperature noted. The calcium chlorid or oil bath acts in the same way as the open water bath.

The writer employs two methods of determining the temperature in the center of a can and the rate of penetration. First, a thermometer is placed in a packing joint which is soldered into the can so that the bulb will just reach the center. By placing a collar an inch above the gasket the can may be submerged in oil and heat applied until a certain temperature is reached. The length of time necessary for the thermometer inside the can to reach the same point as that on the outside, or within from 2 to 5 degrees of the outside, as experience demonstrates may be sufficient, must be allowed in the retort and the heating then continued for such an interval as may be found necessary for sterilization. For example, if the spores of certain organisms are killed at 230° F. in 12 minutes, and it should take 20 minutes to cause the content of the can to become heated, it would require 32 minutes as a minimum for processing, and as a margin of safety the recommendation would be for a longer time, probably for 40 minutes.

The second method of determining temperature in different parts of the retort and in the center of cans is to seal a thermocouple in the can and connect it with a record-

ing apparatus. Thus a time and temperature curve is obtained directly. One of the important points learned from the latter apparatus was the effect of stirring or agitating the contents of cans which ordinarily required long cooking. A can of corn in a retort requiring 65 minutes to reach 245° F. requires only 30 minutes when rolled back and forth. The effect of the agitation was a shorter cooking, a brighter color of the corn, and a bright can on the inside. The principle is good, but some mechanical difficulties in successful operation have yet to be overcome.

The penetration of heat in the can is dependent almost wholly upon the ease with which convection currents are set up, occurring most rapidly in products which permit the free circulation of water, weak brine, or sirup between the solids, as in peas, and least rapidly in the absence of free liquid, as in dry-packed sweet potatoes. Products having a heavy though uniform consistency, like pumpkin and squash, require a long time for heat to penetrate to the center of the can. Heavy tomato pulp takes a much longer time to reach the boiling point than canned tomatoes, and soft ripe fruits, as apricots and peaches, need more time to become sterilized than green fruit, not because the germs are more resistant, but because the heat can not penetrate as readily as when the liquid circulates freely between the solid pieces. Failure to recognize this principle of the movement of heat in liquid, semi-liquid, and solid substances has caused the loss of thousands of cases of foods. Mechanical agitation shortens the period of cooking, especially in foods of heavy body; at the same time it places a greater strain upon the can, with a tendency to increase the number of leakers.

The varying temperatures and methods used in canning cause strains upon the containers, which may be comparatively light or so severe as to cause leakage. The contents expand as the temperature rises above that at which the sealing was done and contract as it goes below that point. The internal pressure, therefore, reaches the maximum in foods packed cold and processed at the boiling point or above in the open, and, conversely, the vacuum is highest in those filled near the boiling point and stored very near that of freezing. If the processing be done in a retort, the internal pressure will be the same as that induced by heating to 212° F., plus the number of pounds used in the retort, but a strain is produced only by such part of the pressure as is developed in bringing the contents to the boiling point as long as the retort is closed. For example, if a can of peas be sealed at 160° F., placed in a retort, and processed at 240° F., the can will first be subjected to a steam pressure of about 10 pounds from without; the internal pressure will rise until the temperature has reached 212° F., at which point the pressure will show about 5 pounds, and as the temperature approaches that of the retort the pressure will show about 15 pounds, only 5 pounds of which will exert any strain until the retort is opened, when the whole becomes effective, gradually decreasing as the cooling takes place.

If, however, when the process is completed, the retort remains closed and a stream of cold water is admitted to chill the cans, the first effect is to condense the steam in the retort suddenly, thus causing a vacuum. This has the effect of removing 15 pounds of atmospheric pressure from the outside of the can or virtually adding the equivalent of that much pressure within, giving a total of about 30 pounds internal strain. This is sufficient to break some cans, particularly No. 3 or above, and accounts for many slow leaks. The more suddenly the strains occur, the greater the percentage of leaks. Processing in retorts is accomplished with little loss, if on admitting the steam the pressure be gradually applied for a few minutes and in turning off a vent be opened and a little time be given to cool.

In order to work the retorts rapidly and avoid the severe strains, air may be introduced under a pressure equal to that of the steam as the latter is being turned off. Water for cooling may then be introduced without danger. By this method square cans, gallon and even 5-gallon cans may be processed without the losses formerly experienced. In the open calcium chlorid or other bath the cans are subjected to the maximum internal pressure throughout the entire operation.

The effect of the sudden production of a vacuum, due to condensing steam inside the cans, may be seen in the strongly collapsed sides when they are played upon by a stream of cold water. Number 3 cans, if a little slack-filled, or gallons will present the appearance of being battered. If such cans, resting upon their sides instead of on end, so that the stream is along the upper side, are struck by cold water, the collapse at the one point may be so severe as to cause buckling or even breaking of seams.

After the processing is completed, the pressure decreases inside the can until, theoretically, it becomes zero at the temperature at which the sealing was done and becomes a vacuum at temperatures below that point. As a matter of fact, however, a weak vacuum is always found at the temperature of sealing, due to changes in the product or to the action of the product upon the container in processing. Cans sealed at 160° to 180° F., and stored at from 60° to 80° F. will show a very strong vacuum, while those packed cold or nearly cold and stored in a warm place will show no vacuum and may show actual pressure, becoming springers.

SANITATION.

A modern cannery is no longer the rough, crude shed that once was thought to be sufficient for this purpose. First of all the location must be sanitary, away from manufacturing processes which of themselves are objectionable, such as soap making, tanning, rendering fats, or any other processes which may give rise to noxious odors or may be productive of organisms of decomposition. The yards and drives about the factory should be cleaned daily, and in summer dust should be prevented by frequent sprinkling or by the application of crude or specially prepared oil to the drives. The application of oil is especially to be recommended where there is much hauling and there is no pavement, or the factory is to be run for a short season only, as in the case of tomatoes. A single application made a couple of weeks before the season opens will suffice for several weeks; if the oil is put on early it will become incorporated in the earth and not be tracked into the factory to any great extent. The drainage must be such as to prevent any surface overflow from adjoining property, and also be ample to keep the stock in good condition at all times. It should be ample to care for the waste, as this is sometimes a serious problem. If the natural body of water available is not sufficient, settling tanks or filters may be necessary. Fermenting material, such as tomato trimmings or corn refuse, should not be tolerated within or near the factory. The supply of water should be sufficient for all purposes and of good quality; that used in washing, blanching, and brining should be free from excessive hardness or iron, otherwise the finished products may be damaged. If the water for this purpose is not naturally of the right quality, artificial treatment may be necessary. The water used for washing about the factory should have a good pressure for cleaning. A factory with a poor location, or an insufficient or poor water supply, has a handicap which is difficult to overcome. The facilities for bringing in or sending out stock should be ample, so that materials used need not be delayed, especially when it may mean deterioration.

The buildings should be designed with reference to the special products to be packed, but there are some features which should be common to all. The ceilings of all rooms should be high, with ample provision for light and ventilation. The light should come from numerous side windows, or, if the rooms are large, from turrets, or a saw-tooth-roof construction. Either of these two arrangements can be made to give a flood of light and at the same time provide good ventilation. An advantage in the saw-tooth construction arises from the cooling and drying effect. When the straight section, or windows, is turned toward the north, the sun beating upon the southern incline will heat the layer of air underneath, causing it to rise. This creates a circulation within the room which tends to dry floors and tables and to lower the temperature. Tests made in factories so constructed have shown several degrees lower temperature on hot days than was recorded in factories having the usual form of roof.

One of the marked contrasts between the newer and older construction is the provision for plenty of light. Light has a beneficial effect upon employees, contributes to cleanliness, and is an active, constant disinfectant. High ceilings and proper roof construction usually render artificial ventilation unnecessary, but if mechanical measures are employed, a blower system with provision for cleaning the air is to be preferred to suction. An abundance of light and air is a combination which will contribute to the maximum of labor efficiency.

A tight, hard floor is a necessity, and in all rooms where manufacturing processes are conducted it should be pitched about $1\frac{1}{2}$ inches for each 10 feet. The pitching should have special reference to the position of machines and tables where there will be more or less water or waste, so that this may be confined and the floors be flushed clean and kept reasonably dry with the minimum of labor. There should be frequent trap connections with the sewer. The kind of material best adapted for a floor will depend in a measure upon whether it is to be used for dry work and storage or whether water is employed more or less freely. Factories having a short packing season, as in the case of tomato canning, find concrete to be the best. Wood shrinks, swells, and cracks with changes of moisture; the cracks are hard to clean, leakage is almost certain to occur, and these conditions become aggravated in factories which are idle a part of the time. Wood with a smooth covering, such as sheet roofing, makes a good floor, but will not last long. Concrete is more or less porous, wears rough, and is not an ideal floor, but is the best for certain conditions. Asphalt wears away and crumbles too easily. Upper floors should not be chosen for food preparation if plenty of ground space is available, for the reason that it is difficult to keep them tight. Furthermore, the work can be supervised to better advantage on one floor than on many, unless the departments are so large as to demand a superintendent in each. Conveyers can be obtained to handle products from one machine to another, and these are more easily kept clean than are floors. Conveyers and overhead tracks should be used in handling the product as far as is possible, in preference to trucks, as the latter are destructive of floors and are not so clean.

The use of slat gratings to cover the floor about the kettles or other places where there is a splashing or overflow of water is especially to be commended. These may be made in sections about 2 by 4 feet, and can be taken up for cleaning. There is no excuse for floors being so wet or sloppy that the workers must wear rubbers, which is sometimes the case. All side walls, partitions, ceilings, and supports should be smooth, to admit of easy cleaning. Preferably they should be light-colored and, as far as possible, of such material as can be washed with a hose, as this is the easiest method of cleaning or of applying whitewash. Some factories need to be divided by partitions to prevent unnecessary heating by steam from the cookers. In other cases the room where the material ready for the can is kept should be separated from the rooms in which the preparation is going on, in order to protect it from dust. That part of the factory in which prepared material is in any way exposed should be screened to keep out flies and dust. This precaution is often of greater importance than the protection of the workroom, as during the working period the moving of machinery and escaping steam will drive away insects.

The tables used in the preparation of foods should be plain and of a material that is easily cleaned. There should be no sharp angles or grooves where waste can accumulate, nor any places beneath where material can be stored. Hardwood, such as maple or ash, is probably the best material for the majority of factories. These woods will absorb little water or juices, they show soil quickly, and clean easily with soap, water, and scrubbing brush. Opal glass or porcelain makes excellent table tops, but is expensive. Enamel-coated metal has come into use, and under certain conditions gives excellent results. The important point is that the tables may be cleaned easily, and that it be done often. The machinery used should be of the most sanitary type and set in such a manner as to be accessible from all sides for cleaning. Con-

vellers for fruits, tomatoes, and all other products should have automatic washers and brushes in their course to keep them clean. The amount and kind of equipment varies greatly, depending upon the product. Peas, corn, and beans require the most, fruits the least. The details of the special requirements will be considered under each product. Water and steam pipes, with hose attachment, should be conveniently placed about the factory for cleaning tables, machines, floors, walls, and ceilings. This is a necessary part of a modern equipment.

Provision should also be made for the cleanliness and comfort of the employees. Water should be placed at convenient places that the workers may wash their hands often, and sanitary drinking fountains installed to take the place of the common cup. A factory is not complete without proper toilet and clothes rooms. The toilet should have facilities for washing the hands with soap and water and hand brushes should be provided. There should be lockers for storing the outer clothes, as wearing apparel should not be hung about the factory. Providing special suits and a manicurist are refinements which are found at some factories and are not so much of an extravagance as less progressive firms would argue. For factories running continuously and employing the same help uniforms are advantageous. For such operations as picking, peeling, and pitting fruits, which may be done as well while sitting as standing, stools should be provided. Standing all day at tables is more than tiring; it is exhausting and decreases efficiency. This is clearly evident to every factory inspector, especially after the season has advanced. The stool is to be preferred to the common bench, so that the individual may stand or sit as may be most comfortable. If standing in one place over cement floors is necessary, wooden springboards should be provided for the restful effect upon the feet. The various States provide the general conditions under which labor may be performed, as age limit, number of working hours in the day or week, and physical condition. No person affected with a disease should be employed in a food factory.

METHODS AND PROCESSES.

The steps in canning will vary with the product, but, in general, there are certain processes which are common to all and may be described in this outline, as receiving the product, grading, washing, preparing for the can, filling, exhausting, capping, processing, and cooling.

RAW MATERIALS.

The first requisite in all canning is that the product be delivered in first-class condition, fresh from the fields or orchard, and in a manner to prevent injury. Fruits, such as berries, must be handled in boxes as for the market, tomatoes in shallow crates, corn, peas, and beans in such quantities that they will not heat, and marine products cold or chilled and in compartments to avoid bruising. The condition of the material on delivery is of the greatest importance, and for that reason the factory should be located near the point of production, or, if shipment be made, it should be for only a short distance and on a direct line. A cannery which depends upon long-distance shipments or purchasing the supplies on a city market will generally be found to put out an inferior article. In any delivery the seller should be held responsible for the condition of the material; the grower has no more right to deliver decayed tomatoes than the canner has to use and ship them. The first case is usually a violation of a State law and should be dealt with accordingly; the second may be reached by Federal statute if the shipment becomes interstate.

GRADING.

The second step, that of grading or sorting for quality, is of great importance. A general inspection or classification of all products is made by the foreman at the time of receipt, but this is insufficient. The real grade of any product depends upon the quality of the original stock rather than upon the sirup or brine added or any sub-

sequent operation, and the best time to make a separation is before the work of preparation is begun. A large part of the sorting can be done better by a few specially trained helpers, although some of it may be continued in subsequent operations. The hard and faulty ears of corn may be picked out more easily while it is being conveyed to the silker than later by the cutter feeders, who are very busy keeping the machines working and can not take the time to sort properly. A few persons can pick out green, defective, and wrinkled tomatoes which will not peel economically and do it better before the fruit reaches the scalding than the peelers can do. The same principle holds true for peaches and many other products. Those who peel or fill the cans should have the minimum of grading to do. The sorting is usually done upon belts or special table tops to expedite the work. Berries are picked, stemmed, and defectives picked out when graded, to save handling.

WASHING.

The next operation is generally that of washing, the method depending upon the material canned. In general, most products are placed in a tank of water to loosen adherent dust and dirt, gently rolled over by the agitation of the water, and then sprayed as they emerge. Since the spraying is the important step, it is desirable that the water have force rather than a large volume. A small spray with force will cut off dirt and adherent mold very successfully. The principle is the same as cleaning a floor with a hose having a nozzle, or with one having an open end; the former will use less water, but will clean better. Some hard-coated products, as peas, are washed in revolving wire cylinders, known as "squirrel cages." Soft fruit, such as raspberries, require very gentle washing, and if the fruit appears clean some packers object to washing it at all, claiming that it causes injury and loss of flavor. Whatever method is used, the cleaning should be thorough.

PREPARATION AND BLANCHING.

Many of the fruits need no special preparation other than cleaning and sorting, after which they are placed directly in the cans. Fruit like peaches, apples, and pears must be peeled and cut to the proper size. Nearly all vegetables require more or less treatment; peas are shelled, graded for size and quality, and washed and blanched by automatic machinery; corn is cut, silked, brined, and cooked; beans are snipped and strung, graded for size, and blanched; asparagus is cut into lengths and blanched; sweet potatoes and beets are peeled and graded, and so on. The operation of blanching is in reality parboiling. Vegetables are dropped into boiling water for from one to five minutes, as a rule, to cause softening, and at the same time to remove some of the mucous substances which form upon the surface. The effect produced by a short boiling in the open as compared with boiling in the closed can is surprising. Peas or beans which are a little aged and hard will soften quickly in the blanch but retain their condition in the can. In almost any case of very cheap peas some may be picked out which, if thrown upon a table or the floor, will bounce a couple of feet or more. This is evidence that they were not properly blanched and that softening did not take place in the can. The operation of blanching is of much importance in putting up good vegetables. It is not a matter of whitening, as the name might seem to indicate, though it does have the effect of producing a much clearer liquor than would otherwise be present.

WASHING AND FILLING THE CANS.

The cans should be washed just prior to being used. In the shipping and storing more or less dirt and dust find lodgment on the inside, and washing is the only method of removing it. The quantity of dirt which can be obtained from a thousand cans is usually a matter of surprise. The work is done very effectively at the present time

by machines. The filling may be done by hand or by machine. There are many products, especially fruits, which can not be successfully filled by machine because of crushing or otherwise injuring them. When filled by hand, the contents should be regulated by weight rather than by volume, so that the finished product will be uniform. If the filling be done by machine, care should be taken to get the best results possible. It is illogical to use care in peeling a 3-inch tomato and then have it squeezed through a 2-inch opening in front of a crude plunger, or that great care should be exercised in washing and blanching peas which are to be run through a filler that will cut or crush enough to make a muddy liquor. Machines should be designed to fill with reference to the nature of the product and not to be merely "can stuffers." Vast improvements have been made in filling machines in the last few years, so that most of the work can be done with nicety and precision. All filling machines operate upon the principle of delivering a certain volume rather than a given weight, and for most products this method is very satisfactory. In all cases, whether the can be filled by weight or volume, the amount of material used should be all that can be put in the can in first-class condition. Brining and siruping have also been improved, the old-fashioned unsanitary dip box giving way to a sanitary filler.

In filling the cans head space equivalent to at least one-fourth of an inch for No. 2 cans and about three-eighths of an inch for No. 2½ and No. 3 cans should be left. The amount of head space needed depends in a measure upon the nature of the product, but without some space the production of a small amount of gas will destroy the vacuum. In the hole and cap cans this space is available, because the sealing can not be done without some room, and as a result springers are rare. The tendency is to overfill the open-top cans. If the product is poured in the cans very hot, 180° F., the expansion which it has undergone will insure sufficient space. In general, any fruit or vegetable sealed at a temperature of 160° F., or higher, will have sufficient head space to prevent springers or flippers. The later types of sanitary capping machines are provided with plungers to squeeze out the overfill of cans. This works well upon such products as have liquids, but fails upon all solids, as sweet potatoes.

EXHAUSTING.

After the cans are filled they should be exhausted—that is, heated until the contents are hot and as much as possible of the air driven out. This process is not considered necessary for articles that are subjected to forecooking, as corn, or for those that are kettle cooked and filled hot, and it is not generally employed with such products as peas and beans, which receive a hot brine, although it is advantageous even under these conditions.

The time required for exhausting depends upon the degree of heat required in the product and the rate at which it penetrates. For such products as corn, peas, beans, pumpkin, squash, and sweet potatoes, a temperature of 180° F., or higher, is desirable. For fruits and tomatoes a temperature of 135° F. will suffice. With good equipment, the work can be done in from one and one-half to eight minutes. For products which will stand the high temperature the steam is turned into the heater under a fairly strong head and the perforated pipe made to spray directly against live steam pipes, so that it may have the effect of superheating. With fruits the heating should be less vigorous and the time rather extended. Too high a temperature causes fruit to swell and float on the top of the sirup, as well as to soften and break open, and it is better to take four or five minutes, rather than two minutes, in reaching 135° F. For hard pears or peaches an eight-minute exhaust will give a better article on the "cut-out"¹ than is obtained by so much extra cooking in the can. For tomatoes a rather

¹ The "cut-out" is the finished product and is judged by appearance, color, consistency, odor, flavor, and weight of contents as a whole and of the solids and liquids separately.

hard exhaust for three minutes is usually employed, but a better result is obtained when a lower temperature is maintained for five or six minutes. Meats and fish are held from 8 to 20 minutes in a vigorous exhaust. Milk is one of the few products packed cold.

One of the difficulties connected with thorough exhausting has been that it causes expansion of the contents, so that the solids float on the top, which makes capping difficult. This is now obviated with the open-top cans by attaching the covers and crimping them lightly before they enter the heater, thus holding the solids in, at the same time permitting the expulsion of air. It also makes possible the sealing at a higher temperature than formerly. The importance of thorough exhausting has been established in connection with studies upon the effect of the contents on the container. Some products which have shown a rather high content of dissolved salts of tin are found to have much less when well exhausted, and practically all show some diminution.

A well-exhausted can shows 8 inches or more of vacuum when the can is cold. The average of a number of experiments gives the vacuum reading at room temperature, where the tipping was 200° F., 16.5 inches; 190°, 15.4 inches; 180°, 13 inches; 170°, 10 inches; 160°, 8.5 inches; 150°, 8 inches; 140°, 7 inches; 130°, 5 inches; and 70°, 1 inch. There are many cans which show 15 inches of vacuum shortly after being put up, but this gradually decreases as the pack stands, the rate depending principally upon the activity with which the product attacks the container.

CAPPING AND TESTING FOR LEAKS.

Open-top cans are sealed by a special machine known as a double seamer. The lid is pressed into place and steel rollers crimp it on without acid or solder. This action is automatic, a single can at a time, but at the rate of 30 per minute, or 1,800 per hour. Cans with solder tops are sealed by automatic machinery, 12 at a time, 85 per minute, or 5,000 per hour. The top is wiped, the cap placed on, acid applied, the hot soldering irons drop into place, and the vent is afterwards closed, all in one series of operations, without touching by hand. As the cans pass from the capping machine they may be submerged in a bath of boiling water to test for leaks. Any imperfection in the can or defect in sealing will be shown by a series of air bubbles issuing from the opening, and the can is at once taken out by the inspector for repairs.

PROCESSING AND COOLING.

After capping, the cans are processed according to the nature of the contents. The cans are collected in large iron baskets, which usually hold 270 No. 2 or 180 No. 3 cans, and three baskets fill a retort. If the processing is conducted at boiling temperature, the retort is not closed, but steam is turned into the water which covers the cans. If the temperature is to be above the boiling point, the retort is closed and either the steam is turned into the retort until the proper pressure and temperature have been reached, or water is first turned in to cover the cans and the steam is admitted until the temperature has been attained. In processing fruits it is customary to use long vats containing boiling water and equipped with automatic conveyers, which carry the cans or crates through at a speed sufficient to process them for the necessary length of time. This period varies with the product. Sterilization depends on administering the proper amount of heat, and heating above the required temperature or for longer than is necessary only cooks the material to no purpose.

As soon as the processing is completed, the cans should be cooled with water. Unless this is done, the heat will be held so long that the contents become overcooked—fruits are softened, and tomatoes become liquid, even blacken, peas break and make muddy liquor, while corn acquires a brown color and a scorched taste. The cooling may be done by turning cold water into the retort, by removing the

basket of cans to a cooling tank, or by spraying with water in the air. There is less difference in the results obtained by different methods of applying either heat or cold than some claim; the important point is to accomplish these steps quickly.

In canning operations the product, salt, sugar, or other seasoning, and water are the only materials used. No hardener, bleach, or preservative is employed, and in commercial canning there never was as much preservative used as is common in the household operation. Saccharin and sulphites were formerly used in corn and peas, but their use has now been practically discontinued; on the other hand the practice of selling a "canning compound" to housewives still continues, and will only cease when the nature and effects of such chemical preservatives are known, and the lack of necessity for their use is appreciated.

CONTAINERS.

The first container used was the ordinary glass bottle with a comparatively small mouth and closed with a cork. The next step was the use of a resinous wax to cover the cork. The bottle was modified to the more convenient or jar form, and a groove run around the top so that a tin cap might be sealed in place with wax. This method of sealing was common in domestic canning until about 1890. The metal screw cap with the rubber ring and various other devices, most of which depend on a rubber or fiber joint to exclude the air, have been introduced since that date. The glass jar is largely used in domestic canning, but not commercially, as it is heavy, breaks easily, can not be handled by automatic machinery, will not stand hard processing without special precautions, and increases freight rates. Glass containers are used for preserves, for spiced and pickled fruits, and for the limited canning for which the consumers are willing to pay a fancy price. Very recently improvements have been made in glass jars and the methods of sealing, which may extend their usefulness, especially to such products as can not be preserved to the best advantage in tin.

The earthenware jar was brought out to offset the high cost of the glass jars; some of these were glazed inside, some outside, and some on both sides. They were generally sealed with a tin cap by means of wax, though a few had earthen tops. Various forms were given to these jars, and some may still be found which have been in use for many years in rural districts. The earthenware jars had only one advantage over glass, that is in cost, but they had the disadvantage of having blow or sand holes. The earthenware jar is not used to any large extent in commercial canning, though some are used to pack bulk jams and stock for preserves, etc.

The tin can is preeminently the container used in commercial canning, and it is also used to a very large extent in home canning. Those used for the latter purpose retain the deep ring about the opening for the insertion of caps and sealing with wax; these are commercially known as wax-top cans. In commercial canning solder is used exclusively for sealing stud hole or cap cans. The tin can has undergone a number of changes. The first cans had flush sides and ends, or plumb joints; these gave way to the stamped-overlapped ends, and all inside solder has been superseded by lock seams and outside soldering. Most solder caps are hemmed, so that only the amount necessary to seal is used. The solder can has been superseded in many cases by the open top, or so-called sanitary can, and in this case the sealing is done by double seaming on the top, no solder being used on the can except in making the side seam. The former objections to acid and solder, on the ground that they contaminated the foodstuffs, have thus been largely overcome.

The most recent improvement in the tin can is the inside coating or lacquering. This type of can is known to the trade as the "enamel lined" can. Various coatings

have been tried at different times without entire success, and while the present lining is not perfect, it does effect a marked improvement in many lines of packing. There are fruits and vegetables which attack the tin coating with more or less vigor, resulting in a loss of color, flavor, and quality, and at the same time form salts of tin which are objectionable. The inside-lacquered cans are especially effective in holding such articles as raspberries, cherries, plums, beets, pumpkin, and hominy. They do not add to such products as corn, peas, beans, tomatoes, or those which have little action upon the tin. Inside coating is accomplished in two ways—by baking the lacquer on the sheet and by spraying it on the inside of the finished can; further improvement in the container may be expected along these lines.

The tin can is made in a great variety of sizes and shapes, but there are certain forms known as standard.

Sizes of standard cans.

Number of can.	Diameter in inches.	Height in inches.	Capacity in ounces.
1	2 $\frac{1}{8}$	4	11.6
1 tall	2 $\frac{1}{8}$	4 $\frac{1}{2}$	12.3
2	3 $\frac{3}{8}$	4 $\frac{9}{16}$	21.3
2 $\frac{1}{2}$	4	4 $\frac{3}{4}$	31.2
3	4 $\frac{5}{16}$	4 $\frac{7}{8}$	35
3 tall	4 $\frac{5}{16}$	5 $\frac{1}{2}$	39
8	6 $\frac{7}{16}$	6 $\frac{7}{8}$	104
10	6 $\frac{3}{4}$	6 $\frac{3}{4}$	107

The size of package used for certain products is fixed by trade custom and not by the needs of the consumer. For example, corn, peas, beans, and such products are almost exclusively packed in No. 2 cans, tomatoes in No. 3, and California fruits in No. 2 $\frac{1}{2}$ cans. The No. 2 can of high-grade peas or corn contains about 22 ounces, or too much for one service for a family of two, three, or four persons, and with peas in particular the unused portion is not so good when served a second time. A can holding 16 ounces would more nearly meet the requirements. The same is true for a No. 3 can of tomatoes. The excess is waste in many cases and represents not only good material but the labor expended upon it, a larger can than is necessary, and boxing and freight. These are all items which contribute to cost and a consequent lessening of the use of canned foods. The No. 2 $\frac{1}{2}$ can was developed as a short weight from the No. 3 and does not adequately represent the interval in size between the No. 2 and the No. 3. The No. 2 $\frac{1}{2}$ sanitary can holds only slightly less than the No. 3 in the older style, as the latter can not be filled so nearly full and sealed. Recently a new style of can has been introduced for California fruits, especially for peaches, known as the luncheon size, which is one-half the height of the No. 2 $\frac{1}{2}$. These are desirable because they will take in the large pieces of fruits and apparently are meeting a demand. The same style in the square can is being used for asparagus tips.

At the present time some packers are trying to meet certain demands by varying the fill rather than the size of the can. For example, a well-filled can of tomatoes might retail at 15 cents, the packer may reduce the quantity, add water, and make the cans sell two for a quarter, or carry it to an extreme and sell for 10 cents. A customer finding that the 10-cent can will furnish the amount of tomato wanted and without waste will repeat the order. The same methods are used more or less in packing fruits, using a quantity which will make the can sell for a certain price. This is a crude, unsatisfactory, and manifestly expensive method, and also open to fraud by those who are unscrupulous. It would be far better for the packer to determine what size is wanted and use such sizes, filling them properly.

THE LABEL.

The label should tell the truth in terms which are direct and easily understood. It should give the name of the article, the grade, by whom packed and where packed, or the name of the distributor. Neither the names nor the illustrations used should be misleading. A picture of green peas in pods in clear relief and subdued type stating that the contents are soaked is hardly appropriate. If given a geographical name it must be the true one. Corn grown in Iowa is not Maine corn though obtained from Maine seed. The use of such terms as "Maine style" for cream corn is in reality only an attempt to circumvent the intent of a true label.

There are no fixed standards for canned goods, though the canner and the trade do recognize and describe certain qualities in jobbing, and prices are made accordingly. The consumer has not been educated to know these differences. The labels usually carry descriptive terms implying superlative quality, as extra select, extra choice, extra fancy, select, choice, fancy, extra standard, and, less commonly, standard. There are too many designations for the same product, and, furthermore, Mr. A's fancy may not be the same as Mr. B's. The grade may not be the same in two consecutive seasons, owing to drought, excess of rain, intense heat, or other cause; neither may it mean the same in different sections of the country in a normal year. In other words, at the present time the grade does not have a fixed character.

Again, when the sirup is one of the factors in grading a product, that fact should be given, though it is not required. A consumer can not go to the grocery and buy peaches in a 40°, 30°, or 20° sirup, though the packers use care in preparing such sirups to use for their different grades. Such designations as heavy, medium, and light sirup are also inadequate. A heavy sirup may mean anything between 35° and 60°, a medium between 20° and 45°, and a light between 10° and 30°, depending on who uses it. These variations are too wide to be carried under such elastic terms. There is no doubt that some fruit packed in light or 20° sirup is just as good as that put up in medium or 30° sirup, but there can be no harm done by giving the exact facts. On general principles, if it is worth while for the packer to select his stock carefully and put up different grades, the consumer should know how to select them.

A can of any food should be as full as it can reasonably be packed and processed without injuring either the quality or appearance of the product. There is such a thing as overfilling as well as underfilling, and one is as much a fault as the other. All foods packed in a liquid or semiliquid condition, or as solids surrounded by liquid, should fill to within one-half inch of the top, and when free liquid is present it should cover the solids. Corn or peas an inch below the top would be a slack fill, even though covered with liquid. The fruits present a more perplexing problem, depending upon the size of the pieces and the degree to which they shrink in the sirup. The very choice large peaches, having only 5 or 6 pieces to the can, will weigh only 18 or 19 ounces and be as full as they can be sealed. A slightly smaller size, of 7 to 9 pieces to the can, will weigh 20 ounces, and for more than 10 pieces the weight will be from 21 to 22 ounces. After they have been cooked in the sirup the pieces will soften, the weight will change, and the fill will not be the same, though in all the amount was as much as could be sealed. If the cans be judged upon weight of the solids alone, the highest grade would be short weight; the quality must also be considered. The presence of only 18 or 19 ounces of low-grade peaches would be manifestly slack filled. Soft berries, like strawberries and raspberries, if filled as full as the can will hold and sirup or water added, will appear only one-third to one-half full of solids upon opening and considerable variation will occur, depending upon their condition. Some foods can be packed so as to give a fairly uniform net weight upon opening, but

with others the volume of solids and its own liquid is a fairer measure. The buyer is entitled to a full can and most packers try to furnish it. The net weights given for several products at the close of the descriptions of processing are intended to represent the minimum; the amount actually obtained should exceed these figures. A lower net weight may be regarded as "slack filled."

USE OF THE TERM "CANNED."

The term "canned" as applied to food products put up in hermetically sealed packages is capable of more than one meaning. Originally it meant any food put up in any container which might be hermetically sealed and the preservation accomplished through sterilization by heat. In commercial use the term "canned" applies only to foods put up in tin containers and sterilized by heat. Under that construction any foods put up in glass or other containers than tin are not rated as commercially canned foods, nor are foods put up in tin in which preservation is accomplished by some means other than heat. Fish cured in brine, pickled, or spiced, but packed in tins, is not canned within this meaning of the term. Fruits preserved with sugar, placed in glass or tin jars, and sealed in vacuum are not canned in the commercial sense. The same is true of smoked meats, such as dried beef, and fish, as smoked herring. In domestic canning glass jars are generally used, and the product is referred to in the home as canned. It is unfortunate that the term should have so many meanings. In the trade it is now common to refer to fruit in glass, sliced bacon and chipped beef in glass or tins, sliced or smoked fish in glass or sardines in tins, and candied fruit in glass.

SPOILAGE.

Spoilage may result from insufficient processing, defective containers, or the use of unfit material. These losses are generally classed under the heads of swells, flat sours, and leaks. Formerly losses were heavy at many factories, but these are becoming less each year, owing to a better knowledge of what is necessary in material, handling and improved appliances. More attention is paid to testing for bacteria, and greater care is taken in obtaining accurate thermometers and gauges, automatic temperature-regulating devices, and time recorders, so that little is left to the judgment of the processor or helper.

Spoilage due to insufficient processing is generally divided into two classes—swells and flat sours. In the former there is generation of gas, causing the ends of the can to become distended; in the latter the content of the can is sour, but there is nothing in the appearance of the can to enable the customer to determine the condition until the can is opened. Swells are generally due to underprocessing good material, while flat sours most often result from giving the regular process to material which has been allowed to stand for some time, such as peas remaining in a load overnight or corn left in a car or in a pile until it begins to heat. The raw material may show no evidence of fermentation on superficial examination, but this condition frequently exists under the conditions just cited. Swells are therefore more likely to be associated with rush operations and flat sours with an overstock or delay in getting at the raw material. It is not intended to give the impression that swells and sours may not occur under other conditions, such as changes in the consistency of the corn, nor that swells may not occur in material which has stood, and sours result from underprocessing, but only to state a general rule.

Swelling or souring may take place shortly after processing or the spoilage may be delayed for weeks or even months. Swelling is more likely to occur and be detected early, while souring is apt to be delayed, though it may occur early. The heat used in

processing may have been insufficient to kill the vegetative forms or spores, but may have injured them to such an extent that time was necessary for recovery and subsequent development. A microscopic examination of the material a few days after processing, or of the incubating cans during a short period, might not show anything wrong. It is only by incubating samples for a number of days that early recognition can be made of some cases of spoilage or possible spoilage. The canner often sends his goods from the factory with full confidence in their condition, and it is not until after they have been in the broker's warehouse or upon the grocer's shelves many weeks or even months that he becomes aware that anything is wrong. The spoilage may amount to only one can to the case, or the percentage may be high; but in either event the goods are rejected with loss.

Spoilage from the use of improper material—i. e., material which has been allowed to stand until fermentation has begun—is generally more or less sour to the smell and taste, but is sterile, the heat of processing having killed the bacteria.

Can leaks may occur along the side, "seam leaks"; at either end, "end leaks"; at the cap, "cap leaks"; at the tip, "tip leaks"; or may be due to defective tin plate. Can making has reached such a point of perfection that manufacturers guarantee all above two to the thousand. These imperfect cans are usually due to the solder not making a perfect union or to defects in crimping or double seaming. With the use of the automatic capping and tipping machines there are fewer leaks than formerly occurred when the work was done by hand; leaks in sanitary cans are generally due to poor adjustment of the rollers. Leakers are recognized, as a rule, by inspection in the hot bath, few getting into the wareroom. Leaks may be very small, even microscopic in size, and, therefore, difficult to detect, or pieces of the can content may be driven into the opening and seal it for the time. Leaks invariably cause swells. A check on spoilage can be kept by placing a few cans from each day's run in a room kept at a high temperature (98°), as these will incubate much more rapidly than if kept in a storeroom. In the laboratory this is done in the ordinary incubator. Since 1903 the writer has used refrigerators in which water tanks are placed in the ice compartment and a heater connected to the outside, the temperature being controlled by a thermo-regulator similar to that used on a chicken incubator. This gives large capacity at low cost and is suitable for small canners. A large chicken incubator has also been used with success.

There are two conditions known to the trade as "springers" and "flippers." A springer is a can the end of which will bulge slightly after a time, but on opening there is found neither gas nor spoilage, though the cans have the appearance of being swells. This condition has been found to be due to overfilling or to packing cold. Such goods when placed in a warm grocery will bulge, owing to the temperature. A flipper is a springer of such mild character that the head may be drawn in by striking the can on a hard object. It is always possible to tell a swell from a springer by the use of a microscope, as in the former there will be large numbers of organisms while in the latter there will be very few.

While a spoiled can of food should never be eaten, the danger of poisoning from fruits and most vegetables is very remote. Ptomain or other poisons may form in meat, milk, and fish, but rarely, if ever, in vegetables.

EFFECT OF HEAT AND COLD.

Canned foods may be injured by an excess of either heat or cold. Some products are injured more than others. The effect of prolonged heating is to cook the contents to a pulp. This is seen at times, in the case of peas and tomatoes in particular, when the cans have been stacked tightly before being fully cooled. The liquor will become cloudy from short heating, thick and heavy from prolonged heating, and the peas

softened and broken if it is continued for a number of days. The writer has seen peas stacked that were warm for three weeks after packing. Tomatoes become soft and pulpy, and often turn a walnut brown if stacked hot and the heat is retained. All fruits become murky and lose their distinctive flavor and odor. Canned foods will stand the high temperature of summer very well, but as far as possible they should not be placed in the hot sun nor kept in a very hot storeroom. The effect of moderate heat is not nearly so marked as might be expected.

Cold seems to have no ill effects upon canned goods unless it goes below the freezing point. Most canned foods will stand a little freezing without appreciable change. Repeated freezing and thawing cause the goods to become flabby and give a flat taste. In all cases the interior of the cans shows a distinct attack upon the tin. With fruits the coating of the cans is made to appear as though it were galvanized. Canned foods will resist a fair degree of heat or cold without serious injury, but continued heat or a very high temperature or repeated freezing and thawing, will cause deterioration in quality.

Foods properly prepared and kept under reasonably good conditions deteriorate very slowly, so that cans carried from one year to another may be as good as, or better than, the latest pack, depending upon the comparative quality of the fresh product used. On general principles, however, it is desirable that a product should not be carried over several seasons. The amount of tin dissolved also increases with time, which is an additional reason for not holding canned goods any longer than is absolutely necessary.

COST OF CANNED FOODS COMPARED WITH FRESH.

In making a comparison of the cost of canned and fresh products of the same kind, a number of factors must be taken into consideration. First, the cost of the raw material and the waste when purchased in the small quantity used in a single meal; second, the cost of labor and preparation used in making it ready for the table. It is obvious that a comparison can not be made for time, as the canned article may be had throughout the year and the fresh for only a limited season, and purchase of a product out of season is usually at a high cost. In making a purchase of either the fresh or canned article, the smaller the quantity, the higher the price; food bought by the single can costs more than if bought by the dozen cans or case, as does the half peck of apples compared with the bushel or barrel. Take, for example, a No. 3 and a No. 10 can of whole apples; the former usually retails for 10 cents and the latter for 25 to 30 cents. Those who can use the latter have a decided advantage, as it will contain between four and five times as much as the former.

There is a vast difference in canned foods, and, as in many other lines of commerce, the cheapest in price is often the most expensive. The can of water-packed tomatoes, the green hard pears, the handful of berries in a pint of water, or poor-quality beans disguised with tomato dressing and offered at a low price, when measured by their food value are the highest. Goods which are strictly standard should give the best food value for the cost. Peas, corn, beans, and tomatoes which are good field run, but which lack the uniformity and niceties which are necessary for the fancy article, will have all the nutritive properties, and be just as palatable, but cost several cents less per dozen. There is much that is pure fad in the purchase of canned foods; the asparagus must be white and the fewest possible stalks in a can; the green is just as good and a medium number of stalks furnish a more edible product. The little peas are, naturally, the costly ones, for less than 5 per cent are of that kind; the large ones are the better flavored and more nutritious, and one-third the cost. Similar examples might be cited of a number of other products. Canned foods should be purchased by the dozen or case, straight or in mixed lots, rather than by single cans.

EXTENT OF THE CANNING INDUSTRY IN THE UNITED STATES.¹*Quantity and value of foods canned, 1899, 1904, 1909.*

Product.	1909		1904		1899	
	Cases.	Value.	Cases.	Value.	Cases.	Value.
Vegetables.....	32,752,469	\$51,568,914	29,597,616	\$45,610,993	19,323,730	\$28,734,598
Tomatoes.....	12,909,986	18,747,941	9,411,084	14,020,846	8,700,538	13,666,560
Corn.....	7,451,265	10,332,136	11,209,597	15,952,386	6,336,984	8,191,383
Peas.....	5,901,703	10,247,363	4,694,492	7,928,791	2,543,722	4,465,673
Beans.....	3,392,864	6,013,098	2,588,015	4,133,810	1,493,517	2,025,123
Asparagus.....	228,559	1,975,775	.....	.....	.....	.....
Pumpkin.....	440,303	576,043	246,557	346,497	138,078	202,404
Sweet potatoes.....	347,286	531,651	192,997	284,385	83,526	124,245
All other.....	2,080,503	3,144,907	1,236,874	2,944,287	27,365	59,210
Fruits.....	5,518,999	12,938,474	4,628,211	11,722,979	4,467,817	11,311,062
Peaches.....	1,484,808	3,753,698	1,304,867	3,902,441	1,449,356	4,283,165
Apples.....	1,205,742	1,898,720	490,341	738,013	645,762	1,125,119
Apricots.....	630,185	1,825,311	539,815	1,641,919	531,648	1,538,252
Pears.....	637,782	1,833,214	789,120	2,192,910	672,485	2,188,201
Berries.....	815,851	1,754,927	489,037	1,058,659	600,419	1,092,975
Cherries.....	390,351	1,019,013	319,350	825,522	114,367	307,788
All others.....	354,280	853,591	695,111	1,363,515	453,780	730,562
<i>Pounds.</i>						
Fish and oysters.....	235,418,713	17,573,311	207,077,976	13,531,786	.....	12,868,572
Salmon.....	99,831,528	8,723,565	48,128,926	4,251,387	62,652,792	5,679,324
Sardines.....	90,694,284	4,931,831	87,224,524	4,380,498	44,951,244	4,212,351
Oysters.....	28,192,392	2,443,101	59,249,043	3,799,412	.....	2,054,800
All other.....	16,700,509	1,474,814	12,475,483	1,100,489	9,625,825	922,097
Condensed milk.....	494,796,544	33,563,129	308,485,182	20,149,282	186,921,787	11,888,792
Sweetened.....	214,518,310	17,345,278	198,355,189	13,478,376	.....	.....
Unsweetened.....	280,278,234	16,217,851	110,129,993	6,670,906	.....	.....
Meats.....	121,376,837	15,345,543	.....	16,144,665	112,443,021	9,166,931
Other products, soups, special- ties, preserves, and pickles.....	.....	43,030,529	.....	35,272,585	.....	35,725,257

PACKING SEASONS.²*Seasons for packing various products in the different States.*

State.	Apples.	Apricots.	Asparagus.	Baked beans.
Arkansas.....	July 23 to Aug. 15	.....	.....	.....
California.....	Sept. 17 to Nov. 26	June 1 to Aug. 10	Mar. 25 to July 1	.....
Colorado.....	Sept. 1 to Oct. 31	.....	May 1 to June 30	.....
Connecticut.....	Sept. 30 to Oct. 30	.....	.....	.....
Delaware.....	Sept. 20 to Oct. 10	.....	.....	.....
Georgia.....	Aug. 1 to Sept. 1	.....	.....	.....
Illinois.....	Aug. 10 to Nov. 15	.....	May 20 to June 20	Jan. to Dec.
Indiana.....	Oct. 1 to Nov. 15	.....	.....	Jan. to Dec.
Kansas.....	Oct. 1 to Oct. 28	.....	.....	.....
Maryland.....	Oct. 1 to Nov. 1	.....	.....	Jan. to Dec.
Massachusetts.....	.....	.....	.....	Jan. to Dec.
Michigan.....	Aug. 1 to Nov. 1	.....	.....	Jan. to Dec.
Minnesota.....	Aug. 15	.....	.....	Jan. to Dec.
Missouri.....	Sept. 18 to Oct. 17	.....	.....	Jan. to Dec.
Nebraska.....	Sept. 1 to Nov. 1	.....	.....	.....
New Jersey.....	.....	.....	May 13 to July 1	Jan. to Dec.
New Mexico.....	Oct. 15 to Dec. 25	Aug. 1 to Aug. 15	.....	.....
New York.....	Sept. 15 to Dec. 31	July 20 to Aug. 20	May 10 to July 15	Jan. to Dec.
Ohio.....	Oct. 1 to Nov. 20	.....	.....	.....
Oregon.....	Aug. 25 to Dec. 1	.....	.....	.....
Pennsylvania.....	July 1 to Dec. 1	.....	.....	.....
Tennessee.....	Oct. to Nov.	.....	Apr. 15 to May 10	.....
Utah.....	July 25 to Dec. 1	July 24 to Oct. 1	Apr. 26 to June 10	.....
Virginia.....	Sept. 1 to Oct. 20	.....	.....	.....
Washington.....	Aug. 15 to Dec. 10	July 1 to Aug. 1	.....	.....

¹ From Thirteenth Census of the United States, 1910, volume X, Manufactures.² From reports of canners.

Seasons for packing various products in the different States—Continued.

State.	String beans.	Beets.	Blackberries.	Cherries.
Arkansas.....			July 1 to Aug. 15	
California.....	Aug. 1 to Sept. 15		May 29 to Sept. 10	May 15 to July 28
Colorado.....				June 15 to Aug. 1
Delaware.....			July 1 to July 20	
Georgia.....	July 1 to Aug. 1		June 10 to June 20	
Illinois.....				June 15 to July 15
Indiana.....	June 1 to Oct. 1			
Kansas.....	June 8 to July 27			
Maryland.....	July 10 to Aug. 20		July 4 to July 20	June 8 to June 30
Michigan.....	June 10 to Sept. 15	July 1 to Oct. 1	July 15 to Aug. 24	June 25 to Aug. 10
Minnesota.....		June 20 to Oct. 22		
Nebraska.....	June 10 to July 15		July 1	July 1
New Jersey.....		June 15 to July 25	July 5 to July 15	June 9 to June 20
New York.....	July 1 to Oct. 28	July 15 to Nov. 25	July 23 to Sept. 1	June 20 to Aug. 1
Ohio.....	July 1 to Sept. 30	June 25 to Nov. 10	July 1 to Aug. 10	June 1 to June 30
Oregon.....	July 15 to Oct. 15		July 15 to Oct. 15	June 10 to Aug. 20
Pennsylvania.....	July 10 to Oct. 15	Aug. 1 to Sept. 15		Aug. 17 to Oct. 1
Tennessee.....	June 15 to July 10		June 15 to July 5	May 25 to June 25
Utah.....	June 30 to Oct. 1			July 1 to Aug. 15
Vermont.....	July 20 to Aug. 20			
Virginia.....	July 20 to Aug. 30		July 1 to Aug. 1	June 1 to June 30
Washington.....				June 25 to July 20
Wisconsin.....	July 10 to Aug. 25			

State.	Corn.	Currants.	Gooseberries.	Grapes.
California.....		June 5 to June 30	May 21 to June 1	Aug. 1 to Dec. 1
Colorado.....		June 15 to Aug. 30	May 15 to June 30	
Delaware.....	July 15 to Sept. 15			
Illinois.....	Aug. 1 to Oct. 1			
Indiana.....	Aug. 1 to Oct. 15			
Iowa.....	Aug. 5 to Oct. 1			
Kansas.....	July 24 to Sept. 15			
Maine.....	Aug. 20 to Sept. 20			
Maryland.....	Aug. 1 to Oct. 20			
Massachusetts.....				
Michigan.....	Sept. 1 to Oct. 1	July 1 to Aug. 1	June 20 to July 30	
Minnesota.....	Aug. 1 to Oct. 1		June 1 to July 1	
Missouri.....	Aug. 10 to Sept. 27			
Nebraska.....	Aug. 1 to Oct. 1			
New Hampshire.....	Aug. 25 to Sept. 20			
New Mexico.....				Sept. 15 to Oct. 1
New York.....	July 26 to Oct. 17	July 1 to Aug. 5	June 20 to Aug. 1	
Ohio.....	Aug. 1 to Nov. 1		June 10 to June 20	
Oregon.....		June 1 to July 15	June 1 to July 10	Sept. 15 to Oct. 30
Pennsylvania.....	Aug. 15 to Oct. 15			
Utah.....			June 15 to July 10	
Vermont.....	Aug. 25 to Sept. 25			
Virginia.....	July 20 to Oct. 20		June 1 to June 30	
Wisconsin.....	Aug. 10 to Oct. 10			

State.	Tommy.	Lima beans.	Okra.	Peaches.
Alabama.....				July 15 to Aug. 15
Arkansas.....				Aug. 1 to Oct. 1
California.....				June 25 to Oct. 25
Colorado.....	Jan. to Dec.			
Delaware.....			Aug. 15 to Sept. 15	July 25 to Aug. 15
Florida.....			June 1 to July 1	
Georgia.....				June 20 to July 25
Illinois.....	Jan. to Dec.			Sept. 10 to Oct. 10
Indiana.....	Jan. to Dec.			
Louisiana.....			July 20 to Aug. 30	
Maryland.....		Aug. 1 to Sept. 1	Aug. 10 to Aug. 30	
Michigan.....		Aug. 15 to Sept. 20		Sept. 11 to Nov. 1
Missouri.....				Aug. 11 to Sept. 5
Nebraska.....				Sept. 10 to Oct. 10
New Jersey.....		Aug. 1 to Sept. 30	June 1 to Sept. 20	
New Mexico.....				Sept. 1 to Oct. 1
New York.....	Jan. to Dec.	July 20 to Oct. 15		Aug. 25 to Oct. 20
Ohio.....	Jan. to Dec.	Aug. 10 to Oct. 30		Aug. 10 to Aug. 31
Oregon.....				Aug. 10 to Oct. 10
Pennsylvania.....	Jan. to Dec.	Aug. 15 to Sept. 15		
Tennessee.....				July 20 to Aug. 20
Texas.....				June 15 to Sept. 1
Utah.....				Sept. 6 to Oct. 6
Virginia.....				Aug. 1 to Oct. 15
Washington.....				July 15 to Sept. 30

Seasons for packing various products in the different States—Continued.

State.	Peas.	Pears.	Pineapples.	Plums.
California.....	May 1 to June 20	July 1 to Oct. 27	.....	July 1 to Sept. 10
Colorado.....	.....	June 15 to Aug. 15	.....	.....
Connecticut.....	.....	.....	Sept. 30 to Oct. 20	.....
Delaware.....	June 1 to June 30	Sept. 20 to Oct. 20	.....	.....
Florida.....	.....	.....	May 15 to Sept. 1	.....
Georgia.....	June 1 to June 15	.....	.....	.....
Illinois.....	June 14 to July 14	.....	.....	.....
Indiana.....	May 26 to July 15	.....	.....	.....
Kansas.....	June 5 to June 30	.....	.....	.....
Maryland.....	June 5 to July 1	Sept. 1 to Nov. 1	.....	.....
Massachusetts.....	.....	Oct. 1 to Nov. 1	June 2 to June 10	.....
Michigan.....	.....	Aug. 20 to Nov. 5	.....	.....
Minnesota.....	June 15 to Aug. 1	.....	.....	.....
New Jersey.....	June 6 to June 25	Oct. 10 to Nov. 15	.....	.....
New Mexico.....	.....	Sept. 15 to Oct. 15	.....	.....
New York.....	June 15 to Aug. 31	Aug. 25 to Nov. 9	May 14 to June 25	Aug. 5 to Sept. 20
Ohio.....	June 1 to July 10	.....	.....	.....
Oregon.....	June 1 to July 20	Aug. 25 to Oct. 10	.....	.....
Tennessee.....	.....	July 25 to Oct. 25	.....	.....
Texas.....	July 1 to Sept. 1	July 15 to Aug. 30	.....	.....
Utah.....	June 10 to July 25	Aug. 26 to Sept. 18	.....	.....
Virginia.....	May 20 to June 19	Sept. 1 to Oct. 15	.....	.....
Washington.....	.....	Aug. 1 to Oct. 15	.....	.....
Wisconsin.....	June 15 to Aug. 28	.....	.....	.....

State.	Pumpkin.	Quince.	Raspberries.	Rhubarb.
Arkansas.....	Oct. 15 to Nov. 15	.....	.....	.....
California.....	Sept. 15 to Jan. 1	Sept. 6 to Nov. 2	June 28 to Oct. 6	.....
Colorado.....	Oct. 1 to Dec. 31	.....	.....	May 15 to June 30
Delaware.....	Oct. 10 to Oct. 20	.....	.....	.....
Illinois.....	Aug. 10 to Nov. 20	.....	.....	.....
Indiana.....	Oct. 1 to Nov. 20	.....	.....	.....
Kansas.....	Oct. 1 to Nov. 24	.....	.....	.....
Maryland.....	Sept. 10 to Oct. 10	.....	.....	.....
Massachusetts.....	.....	Oct. 1	July 3 to July 18	.....
Michigan.....	Oct. 1 to Dec. 25	.....	July 1 to July 15	July 1 to Aug. 1
Minnesota.....	Sept. 25 to Nov. 7	.....	Sept. 1 to Oct. 1	June 1 to July 1
Missouri.....	Sept. 15 to Nov. 15	.....	.....	.....
Nebraska.....	Oct. 1 to Nov. 1	.....	.....	June 1 to July 1
New Jersey.....	Sept. 1 to Nov. 1	.....	.....	.....
New Mexico.....	Nov. 1 to Nov. 15	.....	.....	.....
New York.....	Sept. 10 to Nov. 13	Oct. 1 to Dec. 1	June 25 to Aug. 15	May 15 to July 1
Ohio.....	Sept. 25 to Nov. 24	.....	June 7 to July 20	.....
Oregon.....	Aug. 15 to Dec. 1	.....	June 15 to July 15	June 1 to July 30
Pennsylvania.....	Sept. 20 to Nov. 30	.....	.....	.....
Tennessee.....	Oct. 15 to Nov. 15	.....	June 15 to July 8	.....
Utah.....	Oct. 15 to Nov. 15	.....	July 15 to July 30	May 15 to June 30
Virginia.....	.....	Sept. 1 to Sept. 30	June 1 to June 30	.....
Wisconsin.....	Oct. 10 to Nov. 12	.....	.....	.....

State.	Sauerkraut.	Spinach.	Squash.	Strawberries.
California.....	.....	.....	Nov. 1 to Jan. 1	June 16 to Sept. 28
Colorado.....	Oct. 15 to Mar. 31	.....	.....	May 30 to June 30
Connecticut.....	.....	.....	Sept. 30 to Nov. 20	.....
Delaware.....	.....	.....	Oct. 10 to Oct. 20	June 6 to June 30
Georgia.....	Sept. 1 to Dec. 30	.....	.....	.....
Illinois.....	Sept. 1 to Nov. 1	.....	.....	.....
Indiana.....	Sept. 1 to Apr. 1	.....	.....	.....
Kansas.....	Sept. 1 to Dec. 1	.....	Nov. 2 to Nov. 24	.....
Maryland.....	.....	.....	.....	June 20 to July 4
Massachusetts.....	.....	.....	.....	June 1 to July 8
Michigan.....	.....	.....	.....	June 15 to July 15
Minnesota.....	Dec. 1 to Jan. 1	June 15 to July 1	.....	.....
Nebraska.....	.....	June 1	Oct. to Nov.	.....
New Jersey.....	.....	Sept. 15 to June 25	Sept. 20 to Oct. 30	June 1 to June 21
New Mexico.....	Dec. 26 to Feb. 1	.....	.....	.....
New York.....	.....	June 10 to July 1	Sept. 15 to Dec. 1	May 30 to July 15
Ohio.....	Sept. 11 to Nov. 15	May 25 to Nov. 30	Oct. 1 to Nov. 10	May 25 to June 30
Oregon.....	.....	.....	Sept. 15 to Dec. 1	June 6 to July 20
Tennessee.....	.....	.....	.....	June 1
Texas.....	.....	.....	.....	July 1 to Sept. 1
Utah.....	Aug. 1 to Oct. 20	.....	Oct. 1	.....

Seasons for packing various products in different States—Continued.

State.	Succotash.	Sweet potatoes.	Tomatoes.
Alabama.....		Nov. 1 to Dec. 1	Aug. 1 to Oct. 10
Arkansas.....			Aug. 1 to Oct. 1
California.....			Aug. 8 to Dec. 1
Colorado.....			Aug. 20 to Oct. 1
Connecticut.....			Aug. 15 to Nov. 1
Delaware.....		Oct. 6 to Oct. 18	Aug. 1 to Oct. 20
Georgia.....		Aug. 1 to Sept. 1	Aug. 10 to Oct. 1
Illinois.....			Aug. 10 to Oct. 20
Indiana.....			Aug. 1 to Nov. 1
Iowa.....			Aug. 10 to Oct. 15
Kansas.....		Oct. 8 to Oct. 26	July 27 to Oct. 5
Kentucky.....			Aug. 1 to Sept.
Maryland.....	Aug.	Oct. 10 to Nov. 1	Aug. 20 to Oct. 20
Massachusetts.....			Sept. 1 to Oct. 1
Michigan.....			Aug. 15 to Nov. 1
Minnesota.....			Sept. 1 to Oct. 10
Mississippi.....			July 20 to Oct. 30
Missouri.....			Aug. 20 to Oct. 1
Nebraska.....	Sept. 1		Sept. 1 to Oct. 5
New Jersey.....		Oct. 1 to Nov. 1	Aug. 15 to Oct. 25
New Mexico.....			Aug. 1 to Nov. 1
New York.....	Aug. 15 to Oct. 15		Aug. 1 to Nov. 2
Ohio.....	Aug. 1 to Sept. 15		Aug. 10 to Nov. 15
Oregon.....			Sept. 1 to Nov. 1
Pennsylvania.....	Feb. 15 to Sept. 15		Aug. 1 to Nov. 1
Tennessee.....		Oct. to Nov.	July 15 to Oct. 15
Texas.....		July 1 to Sept. 1	June 15 to Sept. 1
Utah.....			Aug. 7 to Oct. 30
Virginia.....			Aug. 15 to Oct. 15
West Virginia.....			Aug. 1 to Nov. 7
Wisconsin.....			Aug. 15 to Oct. 1

EXPERIMENTAL WORK.

During the season of 1912 an experimental canning laboratory was established in San Francisco for the purpose of studying the problems connected with the canning of fruits. It was located within two blocks of the great fruit market, so that continuous observation could be made of the raw products as they were delivered to the commercial canneries, where the conditions are not very different from those in smaller places. It was also near the food and drug inspection laboratory, thus expediting cooperative work.

The equipment consisted of the usual cookers and machinery found in a first-class canning and preserving factory, only of a smaller size. An eight-horsepower, high-pressure boiler furnished the steam, a five-horsepower motor and a half-horsepower motor the power. The outfit included an open sterilizer, a 22-inch by 36-inch vertical retort fitted for steam or water, with positive circulation, a similar horizontal retort equipped with an agitator, a coil dryer, iron, copper, and aluminum jacketed kettles or preserving pans, an inside enameled iron vacuum pan, a copper vacuum pan, a pasteurizer, and an exhaust box. Two types of closing machines were used, one adjustable for size, in which the can turned, and the other fixed, in which the can remained stationary while being sealed. A vacuum sealing machine was installed for glass jars. A vacuum pump, pressure blower, bottle and can-washing machine, hydraulic press, centrifugal clarifier, bottle filler, cooking coils, peeler, slicer, pulper, and other small apparatus were provided for work in which they might be necessary. Much of the apparatus was so constructed that it could be used for a variety of purposes. The object was to make the dozen or the case the unit of experiments in the regular canning, and from 1 to 10 gallons the unit for the batch in kettle cooking, so that complete records might be kept and the experiment yet be under factory conditions.

The general plan of the experimental work in canning involved the use of under-ripe, prime ripe, overripe, and spoiled fruits of all the varieties canned, to deter-

mine the appearance and effect upon the finished product. The proper fill for the can was obtained by varying the weight from below the normal to one in which more or less crushing was apparent, or by using 450, 500, 550, and 600 grams in a No. 2½ can. The effect of the sirup upon the fruits was observed by using water and 10°, 20°, 30°, 40°, 50°, and 60° sirups. The time of processing varied from 5 to 25 minutes. Nearly all experiments were divided into two lots, one cooled and one not cooled, to note the effect of this treatment. The time of the exhaust was varied on some lines. Two grades of cans were used in a majority of the experiments, the plain tin and the inside-lacquered, both from usual stock as supplied to packers.

These experiments involved the preparation of fruit, weighing it into the cans, and making sirups to exact degrees for more than 5,000 cans. In addition, cooperative work was carried on with a number of canneries in the testing of sirups and in the examination of the pack, the total number of cans from this source examined being about 600. A record of the experimental pack and that of the product sent in involved the weighing of each can as to contents, solids, and sirup, passing upon the commercial grading and the effect upon the can, and in very many instances a chemical examination of the sirup for solids, sugar, and acidity. A microscopical examination was also made to determine the number of organisms present. Each experimental lot was examined shortly after packing and again later to determine the effect of standing. Direct shipments of mixed lots from the experimental pack and also from commercial packs were made by express and by freight direct from San Francisco to La Fayette, Ind., and one by sea from San Francisco to New York and then overland to La Fayette, in order to note the effect of shipments.

During the following winter experiments were conducted to observe the effects of freezing and thawing.

The work was continued in 1913, using some products omitted in 1912, repeating experiments that seemed desirable, and increasing the scope along the lines showing greatest promise of good results. The work still in progress is a determination of the changes effected by standing, the effect of shipping, and of freezing and thawing. The results as far as the work has progressed have been summarized in simple terms under the respective fruits. The purpose has been to eliminate everything that is too technical to be easily understood by the packer or the general public.

In the examination of the details of the experimental work it may appear to those whose experience has been limited to laboratory operations that the individual variations are greater than they should be. For example, the gross weight of individual cans in a set of a dozen or in a case may vary as much as 20 to 50 grams when the fruit has been weighed in and sirup added to make a uniform fill. A part of this variation is due to the effect of exhausting and to the action of the capping machine. Some fruit expands more in exhausting and floats high in the can; consequently it will be thrown off if struck quickly by the plunger preparatory to capping or an excessive amount of sirup may be forced out. In the type of machine in which the can spins while being crimped more or less sirup will be thrown out, depending upon how free it is at the top. The object throughout all the experiments has been to duplicate factory operations and not to attempt to make mathematical standards. The variations indicate the advisability of taking the contents of at least three cans for a composite sample in food analyses or examinations and not to depend upon the contents of one can. They also show that canners can not deliver fixed net weights in cans with the present available methods. Unless otherwise noted the can used is the regular No. 2½.

The method used in draining the fruit was to cut all cans around the outside at the top, leaving the end attached at one point. The end was held in place and the liquid drained by inverting and slowly rotating until all free liquid escaped. This method, which can be used at any place, gives quite uniform results and is more

nearly accurate than one which involves pouring the liquid upon a screen. With such products as tomatoes, which are cooked until they are broken to pieces or mushy, the weight of solids will be a little higher than if a screen were used, but for products which are whole or in separate pieces there will be little difference between the two methods.

The acidity is uniformly expressed in terms calculated as citric acid. The results of the experiments apply only to California products, as in structure and behavior those fruits differ so much from those grown in other sections of the United States that inferences of similar behavior would not be warranted. Practically all the chemical work reported was performed by F. D. Merrill in the San Francisco Food and Drug Inspection Laboratory, and the last analysis by A. W. Broomell in the Bureau of Chemistry.

DETAILED CONSIDERATION OF THE VARIOUS PRODUCTS.

FRUITS.

GENERAL DISCUSSION.

The first essential is that the fruits be harvested when in prime condition, handled with care to prevent injury or bruising, and conveyed with speed from the tree or vine to the factory. For canning purposes it is not necessary, and may not be desirable, that all fruits be as far advanced or as soft as for eating, but they should be ripe, with the flavor characteristic of the ripe fruit. They should not be so far advanced that they will not withstand the ordinary cooking necessary for sterilization without breaking to pieces. The prime condition for canning is that state of maturity in which the flavor and other characteristic qualities have been developed to the maximum and may be retained during sterilization.

Bruised or damaged fruit can not be made attractive, and its use involves heavy waste. The proper handling of the fruit is therefore very important. Apricots, peaches, pears, etc., should be handled in shallow boxes which will not hold more than a bushel and will not admit of more than three or four layers of fruit. The top should be protected with cleats, so that one box can be set upon another without touching the fruit, thus insuring some ventilation. The small fruits—strawberries, raspberries, blackberries, and loganberries—are handled almost exclusively in chests, which are illustrated in detail in Plate II. The California packers have developed this part of the business to a higher degree of perfection than those in any other section of the country. The conical basket used in handling tomatoes in the East should be abolished. The depth is too great and the shape such that the weight of superimposed fruit wedges the lower layers tightly together, causing crushing, rotting, and excessive waste. The baskets are weak, do not stack without bruising or cutting the fruit, and easily become disarranged or broken in shipping.

Rapid transfer of the fruit to the factory after it has been picked is very essential. Deterioration in flavor and weight begins early; conditions favor the growth of organisms, and bacteria, yeast, and mold may develop wherever the fruits press together or the skins are broken. Delicate fruits, such as berries, if picked in the morning should be at the factory in the afternoon, or if picked in the evening should be delivered in the morning. Fruits with hard skins will last much longer, but the rule with all should be quick action. One of the disadvantages of a factory located in a city is the delay in receiving fruit promptly; dependence upon the surplus of the fresh fruit market is hazardous.

One source of trouble and a cause of spoilage of much fruit is contamination from sour and moldy boxes. When a box is used several times it becomes permanently infected and a cause of infection by spoilage organisms. This can be controlled without much difficulty by having a tight room in which the worst boxes are placed

after they are emptied, with steam turned on to saturate the atmosphere and sulphur burned or sulphurous acid gas liberated to act as a disinfectant. This does not require a large place, much time, or expense.

To test the effect of box infection upon spoilage, strawberries, loganberries, and raspberries were obtained and each lot divided into two parts. One part was placed in clean new veneer boxes and the second part in boxes which had been used and become slightly moldy. They were held under the same conditions for 48 hours, at the end of which time each berry was examined. Twenty per cent of those in the new boxes showed some mold, while 80 per cent of those in the used boxes showed infection. When tomatoes cost \$10 a ton, fruits from \$20 to \$50 a ton, and berries from \$50 to \$80 a ton, the importance of reducing the waste from packing to the minimum becomes obvious.

The standard California berry case is made of good lumber and in a careful manner so that it may be used for shipping purposes for several seasons. The length is 41 inches, width 17½ inches, and height 16 inches. The interior is divided by three partitions into four compartments, each with five drawers. The drawer is 15½ inches long, 8½ inches wide, and 2 inches deep. A hinged door closes over the front of the drawers so that they remain securely in place. The material used in the chest is three-quarters of an inch thick, the partitions being 1 inch. The veneer boxes used are 4 by 5 by 1½ inches or 7 by 8 by 1½ inches.

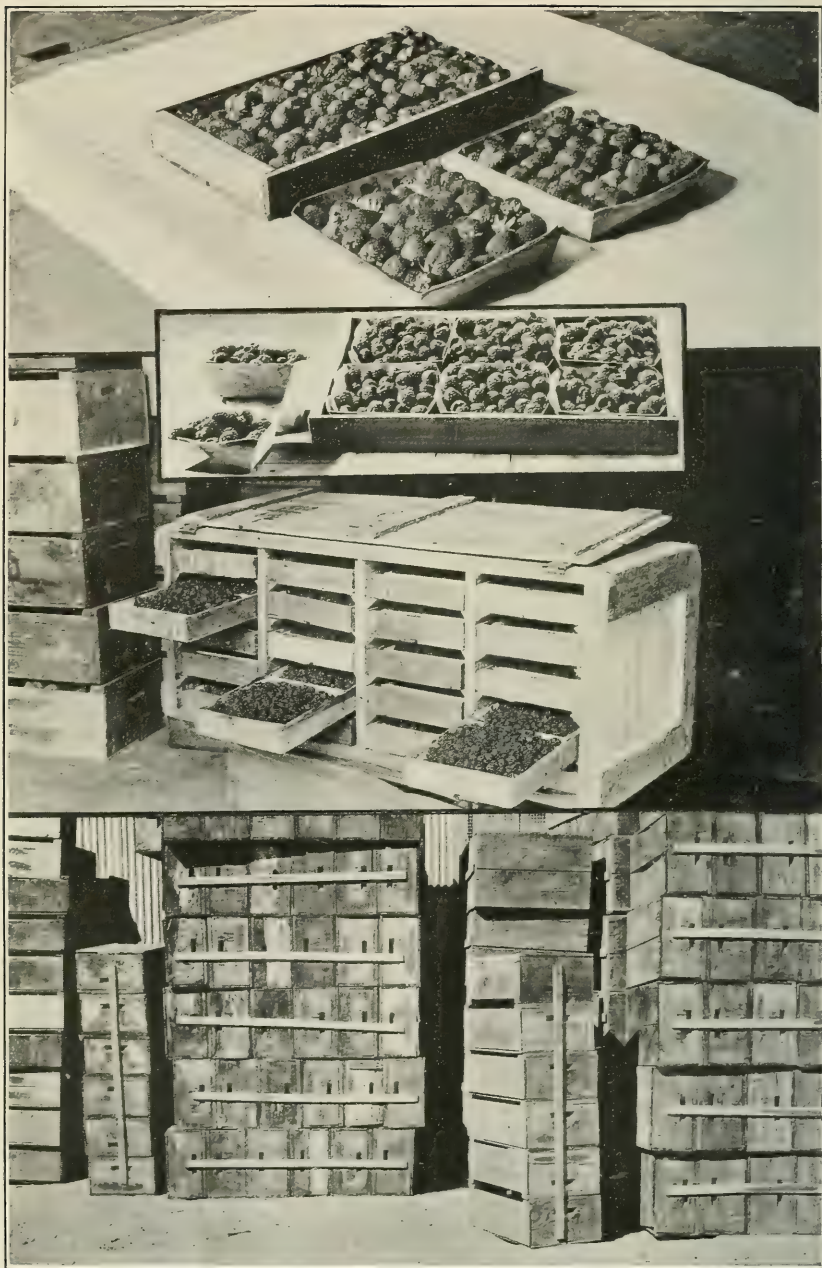
The standard fruit box has the length 24 inches, width 15 inches, and height 9 inches. The material is three-fourths of an inch thick and has stacking guards 1½ inches wide across the ends.

Fruits are the easiest of all articles to can, as subjecting them to a boiling temperature for a short time is sufficient for sterilization in nearly all cases. Formerly it was the practice to pack almost all fruit in No. 3 cans, but recently many changes have been made. Eastern fruits, particularly those of high grade, are packed very largely in the No. 2, while in California the No. 2½ open-top has wholly displaced the No. 3 solder-top cans. The quantity of fruit placed in the No. 2½ open-top can is only slightly less than that held by the old style No. 3. The No. 2 is coming into use on the coast, also the No. 1 flat or picnic size for whole or large fruit, and the No. 1 tall for sliced stock. The picnic size has the same diameter as the No. 2½ but is shorter, being well designed for a small service. A new No. 2 having the same diameter as the No. 2½ has made its appearance. These changes are evidence that the packer realizes the importance of having containers better adapted to packing his products in an attractive form and of having sizes better suited to the needs of the consumer.

In canning fruits the general practice is to fill the cans as level full as is possible without crushing or mashing, and then add the necessary hot sirup to fill the interstices. The amount of fruit used depends upon the variety, the size of pieces, and the state of maturity. When seven or eight large pieces of peaches or pears fill a can, the spaces between them are much greater than when 20 pieces are used. Under such conditions it is obvious that weight alone is not the proper standard for passing judgment, as in the former case the can may be full and contain only 17 or 18 ounces, while in the latter there may be 20 ounces or more. In medium-sized fruits, as peaches, pears, and apricots, a difference of 1 or 2 ounces may easily result from layering the fruits in the cans. This is done with display material in glass, but since it can not be done by machinery that refinement is not used in packing in tin, though some arranging is done on the better grades to insure a fair degree of uniformity in the pack. Such fruits as strawberries and raspberries will differ to the extent of 2 ounces in the packing weight, 20 ounces or more of raspberries being easily packed in a No. 2½ can, while it might require much crushing of strawberries to attain that result. Each product should be packed closely and according to its individual characteristics and not according to a set rule for a whole line.



PEACHES IN STANDARD FRUIT BOXES BEING LOADED INTO A CAR.



THE UPPER FIGURE SHOWS DRAWERS AND CHESTS FOR SHIPPING BERRIES. THE LOWER FIGURE SHOWS THE METHOD OF HANDLING EMPTY FRUIT BOXES.



THE WRONG WAY: STORAGE YARD AND TOMATO-PEELING SHED, WHERE TOMATOES ARE EXPOSED TO THE HEAT OF THE SUN AND TO EARLY SPOILAGE.

The cut-out weight of fruit will not be the same as the weight of fruit introduced, but will vary according to the structure and state of maturity of the fruit and the method of handling. A fruit which is very succulent and has little supporting tissue, such as strawberries or raspberries, undergoes heavy shrinkage, depending upon the strength of the sirup used, while a pear, with its stronger supporting tissue, will suffer little change. The sugar of the sirup unites with the plant juice, and abstracts a part of the water. The fruit loses in weight, the sirup gaining a proportionate amount. The changes in weight, however, are not as great as those in volume. The most marked decrease in the weight of fruit is apparent shortly after processing, after which a gradual increase takes place until the sugar in the fruit and that in the sirup become equalized. Just how much time is required for this process has not been determined.

As an illustration of the changes going on within the can, the analysis of two lots of blackberries and the weights of apricots, cherries, peaches, and pears are given. The first analysis of the blackberries was made the day after canning, the second 70 days later. The weights on the other fruits were taken for the first reading within 30 days after packing and for the second from 120 to 180 days later. The cans were not selected to have a definite and uniform weight, so that the gross weight varies somewhat, but the change in each case goes on in one direction, as is shown in the table. The average given is for seven samples in each set.

The effect of standing on changes in composition of blackberries and on the weight of solids and sirup of apricots, cherries, peaches, and pears.

Kind of fruit and time of standing.	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reducing sugar.	Sucrose.	Acidity (as citric acid).
Blackberries, 50° sirup:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
1 day	1,050	910	384	526	31.6	9.93	18.27	0.42
70 days	1,049	909	428	481	29.1	12.35	13.71	.56
Apricots, standard:								
First reading	992	852	465	387	15.6			
Second reading	1,010	870	553	307	17.7			
Apricots, extra standard:								
First reading	1,023	883	465	418	20.7			
Second reading	1,013	873	563	337	20.0			
Cherries, standard:								
First reading	1,018	875	545	333	18.1			
Second reading	1,013	873	570	303	17.5			
Cherries, extra standard:								
First reading	1,030	890	507	383	21.5			
Second reading	1,027	887	542	345	21.0			
Peaches, standard:								
First reading	977	837	506	331	16.1			
Second reading	979	839	569	277	16.5			
Peaches, extra standard:								
First reading	1,010	870	503	367	22.2			
Second reading	1,025	885	605	280	22.3			
Pears, extra standard:								
First reading	982	842	532	310	16.6			
Second reading	988	848	565	283	17.8			

Unfortunately, systematic data are not available concerning the rate or extent of the changes. Some of the better packers recognize these changes in a practical way by refusing to send out samples of fruits sooner than 30 or 40 days after packing, stating that at first neither the appearance nor the flavor is what it will be after standing. While a heavy sirup tends to soften and shrink ripe fruit, it has less effect on that which is slightly underripe or green. The underripe fruit gives sharper, cleaner-cut edges, especially with peaches, pears, and apricots, and less color and fewer particles of fruit in the sirup. The tendency to exaggerate these points of appearance accounts for the use of some material which would be improved in flavor if it were allowed to mature

more fully. The figures in the table also indicate why the figures which are given by the packer may not agree with those obtained by a purchaser or a food official. The packer does his testing soon after the pack is made and the broker or customer at a later date.

The rate of heating soft fruits has a marked effect upon the fill. This is shown very clearly in the packing of cherries. When a hot 50° or 60° sirup is placed upon Royal Anne cherries, exhausted and processed in the usual way, it causes heavy shrinkage and decided toughening. If the same sirup were applied partly cooled and were then gradually heated to the boiling point, taking from 45 to 60 minutes, there would be very little shrinkage or toughening of the fruit. The same principle holds true with other fruits, much of the shrinkage being due to the rapidity with which the work is done.

EFFECT OF SHIPPING.

One lot of fruit was sent from San Francisco to La Fayette, Ind., by express; another by freight directly, and a third by freight via Panama and New York, while a fourth was held as a control. These lots contained apricots, blackberries, grapes, peaches, plums (green gage and yellow egg), and apples. The grades were water, standard, and extra standard for each line. Later the experimental pack was shipped to Washington. Fruits having a fairly strong skin, such as grapes and green gage plums, were affected to a slight extent by shipping, while very soft fruits, such as loganberries and yellow egg plums, suffered considerable mashing, so that upon draining the solids occupied less space and weighed less than in the control lots. The loss in weight on solids varied from 15 to 90 grams (one-half to 3 ounces) on the very soft fruits, the heaviest loss always being in water or sirup under 30° Balling.

EFFECT OF TIME OF HOLDING.

There seems to be a general impression that canned foods deteriorate with age, but upon this point little direct experimental evidence appears. In these experiments some products have shown deterioration by losing color and flavor and becoming more or less flabby. There is nothing to indicate that they have been injuriously affected, but they are lacking in attractiveness, which, after all, is an element of value in food. Other products have shown a marked improvement on standing, particularly in the development of a fine flavor. Just how much of these changes is due to time has not been determined. Without doubt the process applied, the practice in regard to cooling, whether promptly or not at all, and the temperature at which the foods are held in storage are much more active forces in causing change, and it would require a special set of experiments to determine the effect of time alone. The most marked improvement in flavor was noted in apricots packed at a low temperature, with very appreciable improvement in peaches, blackberries, and strawberries packed at a low temperature and held for two years. A sirup of 20° or more served in some cases as a protection in holding the fruit in a whole condition. The heavy sirup was sufficiently viscous to prevent injury from jarring. The water-packed fruits showed more breaking, increased turbidity of the liquor, and a tendency to settle together more than those with a medium or heavy sirup. The packer seldom has an opportunity to see his product after it has traveled a long distance, and would probably be greatly surprised at the condition of his lower grades as compared with their appearance when they leave the warehouse.

SIRUP.

A proper sirup is a necessity in the packing of most fruits, and has become as much an essential of the grade as the size and quality of the pieces. The sirup may vary from very light to very heavy, or between 10° and 60° on the Balling scale. By common consent the sirups are generally made to be 10°, 20°, 30°, 40°, 50°, or 60° Balling,

though this grading is not strictly followed by all packers. Some use about 2° less and others use 15°, 25°, and 55° to replace 20°, 30°, and 60°. The degree of sirup is arbitrary with the packer and is not indicated upon the label, so that the consumer has nothing as a guide. He can not select a sweet or a tart grade from the information given. The strength of the sirup to be used depends upon the acidity of the fruit, the quantity of fruit, and the flavor desired. Flavor should be the real guide, as much better results can be obtained in developing a good flavor by cooking the sugar into the fruit in canning than by any subsequent addition. With a light weight of fruit in a can, a lighter weight sirup will give the same result on the cut-out as would be given by a heavier sirup on a full pack. Full-weight packing therefore demands not only more fruit than is sometimes found but a correspondingly heavier sirup to secure the same flavor.

The importance of having good, uniform, clean sirup is not fully appreciated by canners. The water used is sometimes unsuitable, being charged with iron or carbonates, which produce a more or less cloudy precipitate and consequent injury to the appearance of the food. The method employed in making the sirup may also cause variation in the readings; correction may not be made for temperature; and cheap and inaccurate hydrometers may be used. The addition of a given quantity of sugar to a tank of water, followed by heating, does not insure uniform distribution, though the sugar may be dissolved. Without thoroughly mixing the contents, a sample taken for a test may give an erroneous reading. All instruments are graduated at a standard temperature, so that correction in the readings is necessary for any variation from the given temperature, a precaution which is frequently neglected. The usual Balling instrument is easily affected by heat, and frequent dipping in and out of hot solutions will cause it to lose its accuracy.

That more might be known concerning the condition of the sirup in the factories, an invitation was issued to 20 canners to send in samples from time to time during the season. A few kindly cooperated. The sample was drawn as it was being delivered to cans of fruit, was processed, and then forwarded to the laboratory. It was taken without the knowledge of the sirup maker, and was thus clearly representative of the sirup in use. The following table shows the results:

Examination of sirups in use at canneries.

Standard.	Highest found.	Lowest found.	Average.	Number of samples.		
				Total.	Above standard.	Below standard.
° Balling.	° Balling.	° Balling.	° Balling.			
60	60.9	60.1	60.6	4	4	0
55	57	37	49.5	9	3	5
50	52	49.6	50.2	3	1	2
40	43.9	25.7	37	37	11	24
30	34.2	18.4	28.8	51	14	31
20	26.5	12.6	21.6	47	15	28
15	21	10.3	14.8	22	8	12
10	21.5	6.1	10.3	43	21	20
				216	77	122

This table itself is evidence that the sirup is not made with sufficient care, or that simpler methods must be used to obtain the correct result. Examination was also made as to color, presence of flocculi or precipitate, effect upon the can, trace of oil, and number of microorganisms. Some factories had a uniformly white, clean sirup, while others had all shades, varying from white to a deep reddish or straw color, depending upon the source of the water supply and its effect upon the can. With clear, soft, or distilled water there was very little attack upon the can, while

with some of the sirups there was a decided rusting, particularly at the ends and along the side seam. When fruit is present the color is not so apparent, either in the sirup or as a deposit on the can. A trace of oil may come from the can, but its presence is more often significant of the use of the overflow from a siruping machine and its contamination there. Large numbers of organisms are usually associated with sirup remaining in the tank overnight or with pipes which have been unused for a rather long period. More organisms are always found with the use of a dip box than with a siruping machine.

From the observations made at factories and as a result of experiments, it is believed that more uniform results can be obtained in the making of sirup by using relatively tall and narrow tanks rather than the wide flat form, so that they may be filled to a given height with water and a certain number of pounds of sugar added which will give the degree of sirup desired. The work could be calculated carefully the first time and corrections made on a scale for temperature, so that the chances for making an error would be reduced to the minimum. The tank should be provided with a stirring device to insure the even distribution of the sugar in the water while it is going into solution. The heating should be accomplished by means of a steam coil rather than by the discharge of steam directly into the sirup. All sirup should be filtered through clean Canton flannel to remove any particles that may be introduced in the handling of the sugar.

For a simple factory test upon a sirup, it is suggested that one or two cans of it be processed in the same manner as the food product upon which it is being used and the can cut after standing for two or three days. If made properly it should be clear and clean.

Sirups are tested by means of a hydrometer, or spindle. This instrument consists of a weighted cylinder having a stem. It is made so that it will float at a given height in water at a temperature of 60° F. If the instrument is placed in a liquid heavier than water it will float, but at a different level. Advantage is taken of this fact, the stem being graduated to indicate different weights or densities of liquids. There are four different kinds of hydrometers used by packers, namely, Balling, Brix, Baumé, and specific gravity. There is no difference between the readings of a Balling and those of a Brix instrument; both indicate the percentage of sugar present in a solution; for example, 20° correspond to 20 per cent of sugar, 20 pounds of sugar and 80 pounds of water. The Baumé hydrometer gives no information directly; the readings must be converted into terms of Brix, which requires the use of tables. This instrument should be discarded. The specific gravity hydrometer gives the weight of the sirup as compared with water, but has little practical use for the canner. All hydrometers are fragile and accurate only for a narrow range of temperature. Tables which give the conversion from one reading to another and also for making the necessary corrections for temperature have been appended (pp. 28-31).

To make a sirup of the various degrees, using 1 gallon of water as a basis, add the following quantities of sugar:

Amount of sugar necessary for sirup of various degrees.

Density, degrees Balling.	Quantity of sugar.			Density, degrees Balling.	Quantity of sugar.		
	Ounces.	Pounds and ounces.	Pounds.		Ounces.	Pounds and ounces.	Pounds.
5	7.0	-- 7	0.44	35	71.75	4 7 $\frac{1}{2}$	4.48
10	14.8	-- 14 $\frac{1}{2}$	.92	40	88.8	5 8 $\frac{1}{2}$	5.55
15	23.5	1 7 $\frac{1}{2}$	1.47	45	109	6 13	6.81
20	30.8	1 14 $\frac{1}{2}$	1.92	50	133.3	8 5 $\frac{1}{2}$	8.33
25	44.5	2 12 $\frac{1}{2}$	2.8	55	163.9	10 4	10.24
30	57.12	3 9	3.57	60	200	12 8	12.5

Weight of sirup per gallon and in No. 2½ can.

Density, degrees Balling.	Weight of sirup.			Density, degrees Balling.	Weight of sirup.		
	Pounds per gallon.	Ounces per can.	Grams per can.		Pounds per gallon.	Ounces per can.	Grams per can.
0	8.34	31.3	887	35	9.62	36.1	1,024
5	8.5	31.9	904	40	9.8	36.9	1,046
10	8.67	32.5	922	45	10.05	37.7	1,069
15	8.84	33.2	941	50	10.27	38.6	1,093
20	9.03	33.9	960	55	10.51	39.3	1,118
25	9.22	34.6	981	60	10.75	40.3	1,144
30	9.41	35.4	1,002				

Average weights of No. 2½ cans of fruits, using different degrees of sirup, and quantity of sugar per can and per case. (Weight of fruit, 560 grams.)

Density of sirup (degrees).	Weight of con- tents.	Weight of sirup.				Weight of sugar per case.		
		Per can.		Per case.				
	<i>Grams.</i>	<i>Grams.</i>	<i>Ounces.</i>	<i>Grams.</i>	<i>Ounces.</i>	<i>Grams.</i>	<i>Lbs.</i>	<i>ozs.</i>
Water.....	835	275	9. 7					
10.....	850	290	10. 23	6, 960	245. 5	696	1	8. 5
20.....	864	304	10. 73	7, 296	257. 5	1, 459	3	3. 5
30.....	876	316	11. 15	7, 584	267. 6	2, 275	5	3
40.....	888	328	11. 57	7, 872	277. 7	3, 149	6	15
50.....	900	340	12	8, 160	288	4, 080	9	0
60.....	915	355	12. 53	8, 520	300. 7	5, 112	11	4. 4

These weights vary slightly for different fruits, and in commercial packing the fill is not quite as strong as in these experiments. The figures, however, will furnish a fairly close guide as to the quantity of sugar required in canning. They also point to a cause of some of the difficulties in correct labeling under the new net-weight law.

Change in volume (in parts per 10,000) of sirups at different temperatures.

Tem- pera- ture.	Volume of sirup.					Tem- pera- ture.	Volume of sirup.				
	10°	20°	30°	40°	50°		10°	20°	30°	40°	50°
° C.						° C.					
5	4.5	7	9	12	16	55	170	183	196	210	229
10	12	16	21	26	32	60	197	209	222	235	253
15	21	28	34	42	50	65	225	236	249	261	278
20	33	41	49	58	69	70	255	265	277	287	306
25	48	57	66	75	88	75	284	295	306	316	332
30	64	74	84	94	110	80	316	325	335	345	360
35	82	92	103	114	132	85	347	355	365	375	388
40	101	112	124	136	156	90	379	387	395	405	417
45	122	134	146	160	180	95	411	418	425	435	445
50	145	156	170	184	204	100	442	450	456	465	473

Relation of Brix, specific gravity, and Baumé.

Per cent of sugar.	Specific gravity.	Degrees Baumé.	Per cent of sugar.	Specific gravity.	Degrees Baumé.	Per cent of sugar.	Specific gravity.	Degrees Baumé.	Per cent of sugar.	Specific gravity.	Degrees Baumé.
0.1	1.0003	0.06	6.6	1.0261	3.7	13.1	1.0531	7.3	19.6	1.0815	10.85
0.2	1.0007	0.11	6.7	1.0265	3.7	13.2	1.0536	7.3	19.7	1.0819	10.9
0.3	1.0011	0.17	6.8	1.0269	3.8	13.3	1.0540	7.4	19.8	1.0824	11.0
0.4	1.0015	0.22	6.9	1.0273	3.8	13.4	1.0544	7.4	19.9	1.0828	11.0
0.5	1.0019	0.28	7.0	1.0277	3.9	13.5	1.0548	7.5	20.0	1.0832	11.1
0.6	1.0023	0.33	7.1	1.0281	3.9	13.6	1.0553	7.5	20.1	1.0837	11.1
0.7	1.0027	0.39	7.2	1.0286	4.0	13.7	1.0557	7.6	20.2	1.0841	11.2
0.8	1.0031	0.44	7.3	1.0290	4.1	13.8	1.0561	7.65	20.3	1.0846	11.2
0.9	1.0034	0.5	7.4	1.0294	4.1	13.9	1.0566	7.7	20.4	1.0850	11.3
1.0	1.0038	0.55	7.5	1.0298	4.2	14.0	1.0570	7.8	20.5	1.0855	11.3
1.1	1.0042	0.6	7.6	1.0302	4.2	14.1	1.0574	7.8	20.6	1.0859	11.4
1.2	1.0046	0.7	7.7	1.0306	4.3	14.2	1.0578	7.9	20.7	1.0864	11.45
1.3	1.0050	0.7	7.8	1.0310	4.3	14.3	1.0583	7.9	20.8	1.0868	11.5
1.4	1.0054	0.8	7.9	1.0314	4.4	14.4	1.0587	8.0	20.9	1.0873	11.6
1.5	1.0058	0.8	8.0	1.0318	4.4	14.5	1.0591	8.0	21.0	1.0877	11.6
1.6	1.0062	0.9	8.1	1.0322	4.5	14.6	1.0596	8.1	21.1	1.0882	11.7
1.7	1.0066	0.9	8.2	1.0327	4.55	14.7	1.0600	8.15	21.2	1.0886	11.7
1.8	1.0070	1.0	8.3	1.0331	4.6	14.8	1.0604	8.2	21.3	1.0891	11.8
1.9	1.0074	1.05	8.4	1.0335	4.7	14.9	1.0609	8.3	21.4	1.0895	11.8
2.0	1.0077	1.1	8.5	1.0339	4.7	15.0	1.0613	8.3	21.5	1.0900	11.9
2.1	1.0081	1.2	8.6	1.0343	4.8	15.1	1.0617	8.4	21.6	1.0904	11.95
2.2	1.0085	1.2	8.7	1.0347	4.8	15.2	1.0621	8.4	21.7	1.0909	12.0
2.3	1.0089	1.3	8.8	1.0351	4.9	14.3	1.0626	8.5	21.8	1.0914	12.05
2.4	1.0093	1.3	8.9	1.0355	4.9	15.4	1.0630	8.5	21.9	1.0918	12.1
2.5	1.0097	1.4	9.0	1.0359	5.0	15.5	1.0634	8.6	22.0	1.0923	12.2
2.6	1.0101	1.4	9.1	1.0364	5.05	15.6	1.0639	8.65	22.1	1.0927	12.2
2.7	1.0105	1.5	9.2	1.0368	5.1	15.7	1.0643	8.7	22.2	1.0932	12.3
2.8	1.0109	1.55	9.3	1.0372	5.2	15.8	1.0647	8.8	22.3	1.0936	12.3
2.9	1.0113	1.6	9.4	1.0376	5.2	15.9	1.0652	8.8	22.4	1.0941	12.4
3.0	1.0117	1.7	9.5	1.0380	5.3	16.0	1.0656	8.9	22.5	1.0945	12.4
3.1	1.0121	1.7	9.6	1.0384	5.3	16.1	1.0660	8.9	22.6	1.0950	12.5
3.2	1.0125	1.8	9.7	1.0388	5.4	16.2	1.0665	9.0	22.7	1.0954	12.55
3.3	1.0129	1.8	9.8	1.0393	5.4	16.3	1.0669	9.0	22.8	1.0959	12.6
3.4	1.0133	1.9	9.9	1.0397	5.5	16.4	1.0674	9.1	22.9	1.0964	12.7
3.5	1.0137	1.9	10.0	1.0401	5.55	16.5	1.0678	9.1	23.0	1.0968	12.7
3.6	1.0141	2.0	10.1	1.0405	5.6	16.6	1.0682	9.2	23.1	1.0973	12.8
3.7	1.0145	2.0	10.2	1.0409	5.7	16.7	1.0687	9.25	23.2	1.0977	12.8
3.8	1.0149	2.1	10.3	1.0413	5.7	16.8	1.0691	9.3	23.3	1.0982	12.9
3.9	1.0153	2.2	10.4	1.0418	5.8	16.9	1.0695	9.4	23.4	1.0986	12.9
4.0	1.0157	2.2	10.5	1.0422	5.8	17.0	1.0700	9.4	23.5	1.0991	13.0
4.1	1.0161	2.3	10.6	1.0426	5.9	17.1	1.0704	9.5	23.6	1.0996	13.0
4.2	1.0165	2.3	10.7	1.0430	5.9	17.2	1.0709	9.5	23.7	1.1000	13.1
4.3	1.0169	2.4	10.8	1.0434	6.0	17.3	1.0713	9.6	23.8	1.1005	13.15
4.4	1.0173	2.4	10.9	1.0439	6.05	17.4	1.0717	9.6	23.9	1.1009	13.2
4.5	1.0177	2.5	11.0	1.0443	6.1	17.5	1.0722	9.7	24.0	1.1014	13.3
4.6	1.0181	2.6	11.1	1.0447	6.2	17.6	1.0726	9.75	24.1	1.1019	13.3
4.7	1.0185	2.6	11.2	1.0451	6.2	17.7	1.0730	9.8	24.2	1.1023	13.4
4.8	1.0189	2.7	11.3	1.0455	6.3	17.8	1.0735	9.9	24.3	1.1028	13.4
4.9	1.0193	2.7	11.4	1.0459	6.3	17.9	1.0739	9.9	24.4	1.1032	13.5
5.0	1.0197	2.8	11.5	1.0464	6.4	18.0	1.0744	10.0	24.5	1.1037	13.5
5.1	1.0201	2.8	11.6	1.0468	6.4	18.1	1.0748	10.0	24.6	1.1042	13.6
5.2	1.0205	2.9	11.7	1.0472	6.5	18.2	1.0753	10.1	24.7	1.1046	13.6
5.3	1.0209	2.9	11.8	1.0476	6.55	18.3	1.0757	10.1	24.8	1.1051	13.7
5.4	1.0213	3.0	11.9	1.0481	6.6	18.4	1.0761	10.2	24.9	1.1056	13.75
5.5	1.0217	3.0	12.0	1.0485	6.7	18.5	1.0766	10.2	25.0	1.1060	13.8
5.6	1.0221	3.1	12.1	1.0489	6.7	18.6	1.0770	10.3	25.1	1.1065	13.9
5.7	1.0225	3.2	12.2	1.0493	6.8	18.7	1.0775	10.35	25.2	1.1070	13.9
5.8	1.0229	3.2	12.3	1.0497	6.8	18.8	1.0779	10.4	25.3	1.1074	14.0
5.9	1.0233	3.3	12.4	1.0502	6.9	18.9	1.0783	10.5	25.4	1.1079	14.0
6.0	1.0237	3.3	12.5	1.0506	6.9	19.0	1.0788	10.5	25.5	1.1083	14.1
6.1	1.0241	3.4	12.6	1.0510	7.0	19.1	1.0792	10.6	25.6	1.1088	14.1
6.2	1.0245	3.4	12.7	1.0514	7.05	19.2	1.0797	10.6	25.7	1.1093	14.2
6.3	1.0249	3.5	12.8	1.0519	7.1	19.3	1.0801	10.7	25.8	1.1097	14.2
6.4	1.0253	3.6	12.9	1.0523	7.2	19.4	1.0806	10.7	25.9	1.1102	14.3
6.5	1.0257	3.6	13.0	1.0527	7.2	19.5	1.0810	10.8	26.0	1.1107	14.35

Relation of Brix, specific gravity, and Baumé—Continued.

Per cent of sugar.	Specific gravity.	Degrees Baumé.	Per cent of sugar.	Specific gravity.	Degrees Baumé.	Per cent of sugar.	Specific gravity.	Degrees Baumé.	Per cent of sugar.	Specific gravity.	Degrees Baumé.
26.1	1.1111	14.4	32.6	1.1422	17.9	39.1	1.1748	21.4	45.6	1.2088	24.9
26.2	1.1116	14.5	32.7	1.1427	18.0	39.2	1.1753	21.5	45.7	1.2093	24.9
26.3	1.1121	14.5	32.8	1.1432	18.0	39.3	1.1758	21.5	45.8	1.2099	25.0
26.4	1.1125	14.6	32.9	1.1437	18.1	39.4	1.1763	21.6	45.9	1.2104	25.0
26.5	1.1130	14.6	33.0	1.1442	18.15	39.5	1.1768	21.6	46.0	1.2110	25.1
26.6	1.1135	14.7	33.1	1.1447	18.2	39.6	1.1773	21.7	46.1	1.2115	25.1
26.7	1.1140	14.7	33.2	1.1452	18.25	39.7	1.1778	21.7	46.2	1.2120	25.2
26.8	1.1144	14.8	33.3	1.1457	18.3	39.8	1.1784	21.8	46.3	1.2126	25.2
26.9	1.1149	14.8	33.4	1.1462	18.4	39.9	1.1789	21.85	46.4	1.2131	25.3
27.0	1.1154	14.9	33.5	1.1466	18.4	40.0	1.1794	21.9	46.5	1.2136	25.35
27.1	1.1158	14.9	33.6	1.1471	18.5	40.1	1.1799	22.0	46.6	1.2142	25.4
27.2	1.1163	15.0	33.7	1.1476	18.5	40.2	1.1804	22.0	46.7	1.2147	25.45
27.3	1.1168	15.1	33.8	1.1481	18.6	40.3	1.1809	22.1	46.8	1.2153	25.5
27.4	1.1172	15.1	33.9	1.1486	18.6	40.4	1.1815	22.1	46.9	1.2158	25.6
27.5	1.1177	15.2	34.0	1.1491	18.7	40.5	1.1820	22.2	47.0	1.2163	25.6
27.6	1.1182	15.2	34.1	1.1496	18.7	40.6	1.1825	22.2	47.1	1.2169	25.7
27.7	1.1187	15.3	34.2	1.1501	18.8	40.7	1.1830	22.3	47.2	1.2174	25.7
27.8	1.1191	15.3	34.3	1.1506	18.85	40.8	1.1835	22.3	47.3	1.2180	25.8
27.9	1.1196	15.4	34.4	1.1511	18.9	40.9	1.1840	22.4	47.4	1.2185	25.8
28.0	1.1201	15.4	34.5	1.1516	18.95	41.0	1.1846	22.4	47.5	1.2191	25.9
28.1	1.1206	15.5	34.6	1.1521	19.0	41.1	1.1851	22.5	47.6	1.2196	25.9
28.2	1.1210	15.55	34.7	1.1526	19.1	41.2	1.1856	22.5	47.7	1.2201	26.0
28.3	1.1215	15.6	34.8	1.1531	19.1	41.3	1.1861	22.6	47.8	1.2207	26.0
28.4	1.1220	15.7	34.9	1.1536	19.2	41.4	1.1866	22.65	47.9	1.2212	26.1
28.5	1.1225	15.7	35.0	1.1541	19.2	41.5	1.1872	22.7	48.0	1.2218	26.1
28.6	1.1229	15.8	35.1	1.1546	19.3	41.6	1.1877	22.75	48.1	1.2223	26.2
28.7	1.1234	15.8	35.2	1.1551	19.3	41.7	1.1882	22.8	48.2	1.2229	26.2
28.8	1.1239	15.9	35.3	1.1556	19.4	41.8	1.1887	22.9	48.3	1.2234	26.3
28.9	1.1244	15.9	35.4	1.1561	19.4	41.9	1.1892	22.9	48.4	1.2240	26.35
29.0	1.1248	16.0	35.5	1.1566	19.5	42.0	1.1898	23.0	48.5	1.2245	26.4
29.1	1.1253	16.0	35.6	1.1571	19.55	42.1	1.1903	23.0	48.6	1.2250	26.45
29.2	1.1258	16.1	35.7	1.1576	19.6	42.2	1.1908	23.1	48.7	1.2256	26.5
29.3	1.1263	16.1	35.8	1.1581	19.65	42.3	1.1913	23.1	48.8	1.2261	26.6
29.4	1.1267	16.2	35.9	1.1586	19.7	42.4	1.1919	23.2	48.9	1.2267	26.6
29.5	1.1272	16.25	36.0	1.1591	19.8	42.5	1.1924	23.2	49.0	1.2272	26.7
29.6	1.1277	16.3	36.1	1.1596	19.8	42.6	1.1929	23.3	49.1	1.2278	26.7
29.7	1.1282	16.4	36.2	1.1601	19.9	42.7	1.1934	23.3	49.2	1.2283	26.8
29.8	1.1287	16.4	36.3	1.1606	19.9	42.8	1.1940	23.4	49.3	1.2289	26.8
29.9	1.1291	16.5	36.4	1.1611	20.0	42.9	1.1945	23.45	49.4	1.2294	26.9
30.0	1.1296	16.5	36.5	1.1616	20.0	43.0	1.1950	23.5	49.5	1.2300	26.9
30.1	1.1301	16.6	36.6	1.1621	20.1	43.1	1.1955	23.55	49.6	1.2305	27.0
30.2	1.1306	16.6	36.7	1.1626	20.1	43.2	1.1961	23.6	49.7	1.2311	27.0
30.3	1.1311	16.7	36.8	1.1631	20.2	43.3	1.1966	23.7	49.8	1.2316	27.1
30.4	1.1315	16.7	36.9	1.1636	20.2	43.4	1.1971	23.7	49.9	1.2322	27.1
30.5	1.1320	16.8	37.0	1.1641	20.3	43.5	1.1976	23.8	50.0	1.2327	27.2
30.6	1.1325	16.85	37.1	1.1646	20.35	43.6	1.1982	23.8	50.1	1.2333	27.2
30.7	1.1330	16.9	37.2	1.1651	20.4	43.7	1.1987	23.9	50.2	1.2338	27.3
30.8	1.1335	17.0	37.3	1.1656	20.5	43.8	1.1992	23.9	50.3	1.2344	27.3
30.9	1.1340	17.0	37.4	1.1661	20.5	43.9	1.1998	24.0	50.4	1.2349	27.4
31.0	1.1344	17.1	37.5	1.1666	20.6	44.0	1.2003	24.0	50.5	1.2355	27.45
31.1	1.1349	17.1	37.6	1.1671	20.6	44.1	1.2008	24.1	50.6	1.2361	27.5
31.2	1.1354	17.2	37.7	1.1676	20.7	44.2	1.2013	24.1	50.7	1.2366	27.55
31.3	1.1359	17.2	37.8	1.1681	20.7	44.3	1.2019	24.2	50.8	1.2372	27.6
31.4	1.1364	17.3	37.9	1.1686	20.8	44.4	1.2024	24.2	50.9	1.2377	27.7
31.5	1.1369	17.3	38.0	1.1692	20.8	44.5	1.2029	24.3	51.0	1.2383	27.7
31.6	1.1374	17.4	38.1	1.1697	20.9	44.6	1.2035	24.35	51.1	1.2388	27.8
31.7	1.1378	17.4	38.2	1.1702	20.9	44.7	1.2040	24.4	51.2	1.2394	27.8
31.8	1.1383	17.5	38.3	1.1707	21.0	44.8	1.2045	24.45	51.3	1.2399	27.9
31.9	1.1388	17.55	38.4	1.1712	21.05	44.9	1.2051	24.5	51.4	1.2405	27.9
32.0	1.1393	17.6	38.5	1.1717	21.1	45.0	1.2056	24.6	51.5	1.2411	28.0
32.1	1.1398	17.7	38.6	1.1722	21.15	45.1	1.2061	24.6	51.6	1.2416	28.0
32.2	1.1403	17.7	38.7	1.1727	21.2	45.2	1.2067	24.7	51.7	1.2422	28.1
32.3	1.1408	17.8	38.8	1.1732	21.3	45.3	1.2072	24.7	51.8	1.2427	28.1
32.4	1.1412	17.8	38.9	1.1737	21.3	45.4	1.2077	24.8	51.9	1.2433	28.2
32.5	1.1417	17.9	39.0	1.1743	21.4	45.5	1.2083	24.8	52.0	1.2439	28.2

Relation of Brix, specific gravity, and Baumé—Continued.

Per cent of sugar.	Specific gravity.	Degrees Baumé.	Per cent of sugar.	Specific gravity.	Degrees Baumé.	Per cent of sugar.	Specific gravity.	Degrees Baumé.	Per cent of sugar.	Specific gravity.	Degrees Baumé.
52.1	1.2444	28.3	58.6	1.2816	31.6	65.1	1.3205	34.95	71.6	1.3610	38.2
52.2	1.2450	28.3	58.7	1.2822	31.7	65.2	1.3211	35.0	71.7	1.3616	38.2
52.3	1.2455	28.4	58.8	1.2828	31.7	65.3	1.3217	35.05	71.8	1.3623	38.2
52.4	1.2461	28.4	58.9	1.2834	31.8	65.4	1.3223	35.1	71.9	1.3629	38.3
52.5	1.2467	28.5	59.0	1.2840	31.85	65.5	1.3229	35.15	72.0	1.3635	38.3
52.6	1.2472	28.5	59.1	1.2845	31.9	65.6	1.3235	35.2	72.1	1.3642	38.4
52.7	1.2478	28.6	59.2	1.2851	31.95	65.7	1.3241	35.25	72.2	1.3648	38.4
52.8	1.2483	28.65	59.3	1.2857	32.0	65.8	1.3247	35.3	72.3	1.3655	38.5
52.9	1.2489	28.7	59.4	1.2863	32.05	65.9	1.3253	35.35	72.4	1.3661	38.5
53.0	1.2495	28.75	59.5	1.2869	32.1	66.0	1.3260	35.4	72.5	1.3667	38.6
53.1	1.2500	28.8	59.6	1.2875	32.15	66.1	1.3266	35.4	72.6	1.3674	38.6
53.2	1.2506	28.85	59.7	1.2881	32.2	66.2	1.3272	35.5	72.7	1.3680	38.7
53.3	1.2512	28.9	59.8	1.2887	32.3	66.3	1.3278	35.5	72.8	1.3687	38.7
53.4	1.2517	28.9	59.9	1.2893	32.3	66.4	1.3285	35.6	72.9	1.3693	38.8
53.5	1.2523	29.0	60.0	1.2898	32.4	66.5	1.3291	35.6	73.0	1.3699	38.8
53.6	1.2529	29.1	60.1	1.2904	32.4	66.6	1.3297	35.7	73.1	1.3705	38.9
53.7	1.2534	29.1	60.2	1.2910	32.5	66.7	1.3303	35.7	73.2	1.3712	38.9
53.8	1.2540	29.2	60.3	1.2916	32.5	66.8	1.3309	35.8	73.3	1.3719	39.0
53.9	1.2546	29.2	60.4	1.2922	32.6	66.9	1.3315	35.8	73.4	1.3725	39.0
54.0	1.2551	29.3	60.5	1.2928	32.6	67.0	1.3322	35.9	73.5	1.3732	39.1
54.1	1.2557	29.3	60.6	1.2934	32.7	67.1	1.3327	35.9	73.6	1.3738	39.1
54.2	1.2563	29.4	60.7	1.2940	32.7	67.2	1.3334	36.0	73.7	1.3745	39.2
54.3	1.2568	29.4	60.8	1.2946	32.8	67.3	1.3340	36.0	73.8	1.3751	39.2
54.4	1.2574	29.5	60.9	1.2952	32.8	67.4	1.3346	36.1	73.9	1.3757	39.3
54.5	1.2580	29.5	61.0	1.2958	32.9	67.5	1.3352	36.1	74.0	1.3764	39.3
54.6	1.2585	29.6	61.1	1.2964	32.9	67.6	1.3359	36.2	74.1	1.3770	39.4
54.7	1.2591	29.6	61.2	1.2970	33.0	67.6	1.3365	36.2	74.2	1.3777	39.4
54.8	1.2597	29.7	61.3	1.2975	33.0	67.8	1.3371	36.3	74.3	1.3783	39.5
54.9	1.2602	29.7	61.4	1.2981	33.1	67.9	1.3377	36.3	74.4	1.3790	39.5
55.0	1.2608	29.8	61.5	1.2987	33.1	68.0	1.3384	36.4	74.5	1.3796	39.6
55.1	1.2614	29.8	61.6	1.2993	33.2	68.1	1.3390	36.4	74.6	1.3803	39.6
55.2	1.2620	29.9	61.7	1.2999	33.2	68.2	1.3396	36.5	74.7	1.3809	39.7
55.3	1.2625	29.9	61.8	1.3005	33.3	68.3	1.3402	36.5	74.8	1.3816	39.7
55.4	1.2631	30.0	61.9	1.3011	33.3	68.4	1.3408	36.6	74.9	1.3822	39.8
55.5	1.2637	30.05	62.0	1.3017	33.4	68.5	1.3415	36.6	75.0	1.3828	39.8
55.6	1.2642	30.1	62.1	1.3023	33.4	68.6	1.3421	36.7	75.1	1.3835	39.9
55.7	1.2648	30.15	62.2	1.3029	33.5	68.7	1.3427	36.7	75.2	1.3842	39.9
55.8	1.2654	30.2	62.3	1.3035	33.5	68.8	1.3433	36.8	75.3	1.3848	40.0
55.9	1.2660	30.25	62.4	1.3041	33.6	68.9	1.3440	36.8	75.4	1.3855	40.0
56.0	1.2665	30.3	62.5	1.3047	33.6	69.0	1.3446	36.9	75.5	1.3861	40.1
56.1	1.2671	30.4	62.6	1.3053	33.7	69.1	1.3452	36.9	75.6	1.3868	40.1
56.2	1.2677	30.4	62.7	1.3059	33.7	69.2	1.3458	37.0	75.7	1.3874	40.2
56.3	1.2683	30.5	62.8	1.3065	33.8	69.3	1.3465	37.0	75.8	1.3880	40.2
56.4	1.2688	30.5	62.9	1.3071	33.8	69.4	1.3471	37.1	75.9	1.3887	40.3
56.5	1.2694	30.6	63.0	1.3077	33.9	69.5	1.3477	37.1	76.0	1.3894	40.3
56.6	1.2700	30.6	63.1	1.3083	33.9	69.6	1.3484	37.2	76.1	1.3900	40.4
56.7	1.2706	30.7	63.2	1.3089	34.0	69.7	1.3490	37.2	76.2	1.3907	40.4
56.8	1.2712	30.7	63.3	1.3095	34.0	69.8	1.3496	37.3	76.3	1.3913	40.5
56.9	1.2717	30.8	63.4	1.3101	34.1	69.9	1.3502	37.3	76.4	1.3920	40.5
57.0	1.2723	30.8	63.5	1.3107	34.1	70.0	1.3509	37.4	76.5	1.3926	40.6
57.1	1.2729	30.9	63.6	1.3113	34.2	70.1	1.3515	37.4	76.6	1.3933	40.6
57.2	1.2735	30.9	63.7	1.3119	34.2	70.2	1.3521	37.5	76.7	1.3940	40.7
57.3	1.2740	31.0	63.8	1.3126	34.3	70.3	1.3528	37.5	76.8	1.3946	40.7
57.4	1.2746	31.0	63.9	1.3132	34.3	70.4	1.3534	37.6	76.9	1.3953	40.8
57.5	1.2752	31.1	64.0	1.3138	34.4	70.5	1.3540	37.6	77.0	1.3959	40.8
57.6	1.2758	31.1	64.1	1.3144	34.4	70.6	1.3546	37.7	77.1	1.3966	40.8
57.7	1.2764	31.2	64.2	1.3150	34.5	70.7	1.3553	37.7	77.2	1.3972	40.9
57.8	1.2769	31.2	64.3	1.3156	34.5	70.8	1.3559	37.8	77.3	1.3979	41.0
57.9	1.2775	31.3	64.4	1.3162	34.6	70.9	1.3565	37.8	77.4	1.3986	41.0
58.0	1.2781	31.3	64.5	1.3168	34.6	71.0	1.3572	37.9	77.5	1.3992	41.0
58.1	1.2787	31.4	64.6	1.3174	34.7	71.1	1.3578	37.9	77.6	1.3999	41.1
58.2	1.2793	31.4	64.7	1.3180	34.7	71.2	1.3585	38.0	77.7	1.4005	41.1
58.3	1.2799	31.5	64.8	1.3186	34.8	71.3	1.3591	38.0	77.8	1.4012	41.2
58.4	1.2804	31.5	64.9	1.3192	34.8	71.4	1.3597	38.1	77.9	1.4019	41.2
58.5	1.2810	31.6	65.0	1.3198	34.9	71.5	1.3604	38.1	78.0	1.4025	41.3

Relation of Brix, specific gravity, and Baumé—Continued.

Per cent of sugar.	Specific gravity.	Degrees Baumé.	Per cent of sugar.	Specific gravity.	Degrees Baumé.	Per cent of sugar.	Specific gravity.	Degrees Baumé.	Per cent of sugar.	Specific gravity.	Degrees Baumé.
78.1	1.4032	41.3	80.1	1.4165	42.3	82.1	1.4300	43.3	84.1	1.4437	44.2
78.2	1.4039	41.4	80.2	1.4172	42.3	82.2	1.4307	43.3	84.2	1.4443	44.3
78.3	1.4045	41.4	80.3	1.4179	42.4	82.3	1.4314	43.4	84.3	1.4450	44.3
78.4	1.4052	41.5	80.4	1.4185	42.4	82.4	1.4320	43.4	84.4	1.4457	44.3
78.5	1.4058	41.5	80.5	1.4192	42.5	82.5	1.4327	43.5	84.5	1.4464	44.4
78.6	1.4065	41.6	80.6	1.4199	42.5	82.6	1.4334	43.5	84.6	1.4471	44.4
78.7	1.4072	41.6	80.7	1.4205	42.6	82.7	1.4341	43.5	84.7	1.4478	44.5
78.8	1.4078	41.7	80.8	1.4212	42.6	82.8	1.4348	43.6	84.8	1.4485	44.5
78.9	1.4085	41.7	80.9	1.4219	42.7	82.9	1.4354	43.6	84.9	1.4492	44.6
79.0	1.4092	41.8	81.0	1.4226	42.7	83.0	1.4361	43.7	85.0	1.4498	44.6
79.1	1.4098	41.8	81.1	1.4232	42.8	83.1	1.4368	43.7	85.1	1.4505	44.7
79.2	1.4105	41.9	81.2	1.4239	42.8	83.2	1.4375	43.8	85.2	1.4512	44.7
79.3	1.4112	41.9	81.3	1.4246	42.9	83.3	1.4382	43.8	85.3	1.4519	44.8
79.4	1.4119	42.0	81.4	1.4253	42.9	83.4	1.4388	43.9	85.4	1.4526	44.8
79.5	1.4125	42.0	81.5	1.4259	43.0	83.5	1.4395	43.9	85.5	1.4533	44.9
79.6	1.4132	42.1	81.6	1.4266	43.0	83.6	1.4402	44.0	85.6	1.4540	44.9
79.7	1.4138	42.1	81.7	1.4273	43.1	83.7	1.4409	44.0	85.7	1.4547	45.0
79.8	1.4145	42.2	81.8	1.4280	43.1	83.8	1.4416	44.1	85.8	1.4554	45.0
79.9	1.4152	42.2	81.9	1.4287	43.2	83.9	1.4423	44.1	85.9	1.4561	45.1
80.0	1.4158	42.2	82.0	1.4293	43.2	84.0	1.4430	44.2	86.0	1.4568	45.1

Correction for the readings of Balling's saccharimeter, on account of temperature.

TO BE SUBTRACTED FROM THE DEGREE READ.

Temp.	Per cent of sugar in solution.												
C.	0	5	10	15	20	25	30	35	40	50	60	70	75
13	0.14	0.18	0.19	0.21	0.22	0.24	0.26	0.27	0.28	0.29	0.33	0.35	0.39
14	.12	.15	.16	.17	.18	.19	.21	.22	.22	.23	.26	.28	.32
15	.09	.11	.12	.14	.14	.15	.16	.17	.16	.17	.19	.21	.25
16	.06	.07	.08	.09	.10	.10	.11	.12	.12	.12	.14	.16	.18
17	.02	.02	.03	.03	.03	.04	.04	.04	.04	.04	.05	.05	.06

TO BE ADDED TO THE DEGREE READ.

18	.02	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.02
19	.06	.08	.08	.09	.09	.10	.10	.10	.10	.10	.10	.08	.06
20	.11	.14	.15	.17	.17	.18	.18	.18	.19	.19	.18	.15	.11
21	.16	.20	.22	.24	.24	.25	.25	.25	.26	.26	.25	.22	.18
22	.21	.26	.29	.31	.31	.32	.32	.32	.33	.34	.32	.29	.25
23	.27	.32	.35	.37	.38	.39	.39	.39	.40	.42	.39	.36	.33
24	.32	.38	.41	.43	.44	.46	.46	.47	.47	.50	.46	.43	.40
25	.37	.44	.47	.49	.51	.53	.54	.55	.55	.58	.54	.51	.48
26	.43	.50	.54	.56	.58	.60	.61	.62	.62	.66	.62	.58	.55
27	.49	.57	.61	.63	.65	.68	.68	.69	.70	.74	.70	.65	.62
28	.56	.64	.68	.70	.72	.76	.76	.78	.78	.82	.78	.72	.70
29	.63	.71	.75	.78	.79	.84	.84	.86	.86	.90	.86	.80	.78
30	.70	.78	.82	.87	.87	.92	.92	.94	.94	.98	.94	.88	.86

While the Brix or Balling spindle gives the percentage of sugar in a sirup, this is not true for the fruit sirup, where the reading indicates soluble solids and is always higher than the actual sugar content. As will be seen in following the tables on fruits, the Balling reading serves, however, as an excellent index for the sirup used, and in the establishment of grades should be used on the cut-out, rather than the quantity of sugar claimed to have been added. In the trade fruits graded as extra and special extra are put up in heavy sirup; extra standard and standard, in medium sirup; and

sometimes standard and seconds, in light sirup. Those packed without sirup are known as water or pie fruit.

There is no chemical difference between a high-grade granulated sugar made from sugar cane and one made from sugar beets, though canners have been taught that there is a difference in favor of cane sugar and pay a premium of from 10 to 20 cents per hundred pounds for it. Some of the best packers make no discrimination now except on the basis of price. Both kinds of sugar were used in the experimental work and no difference was observed except in one case of beet sugar, in which the difference was apparently due to the sulphids present. A rather ashen gray color was given to white cherries and the delicate color in some of the berries was destroyed. Chemical tests showed the presence of sulphid, and leaving a silver or aluminum spoon in the sugar overnight was sufficient to cause blackening. How far such troubles extend in canning is not known.

APPLES (*PYRUS MALUS*).

Apples used for canning should be of varieties that cook well. They should be slightly acid, smooth and sound, and without bruised spots. Poor apples can not be used in canning and make a first-class product. The peeling is done by hand or power peelers and the core removed by the same operation or with a coring machine. Apples which are intended for dumplings are left whole and graded into sizes to give a certain number to the can, but those intended for pies or other cooking purposes are sliced in quarters or smaller pieces. The peeled apple is placed in cans as quickly as possible and hot water added to make the fill. If the apples can not be packed in the can at once, they are held in tubs of cold water to prevent their oxidizing or turning brown. The process on apples is about 8 minutes at 212° F. for No. 3 cans and about 10 minutes for No. 10 cans.

The waste in the proportion of good apples will be from 20 to 40 per cent, depending in a measure upon whether they are cut into small slices for pie stock or allowed to remain whole for dumplings. The waste is used for jelly stock, and dried for chops and vinegar. The method of utilization depends upon the quality.

APRICOTS (*PRUNUS ARMENIACA*).

The apricot is produced for canning and drying in its highest state of development in California. It is one of the good fruits with a distinctive and agreeable flavor, although this is not developed until the fruit is ripe and ready to turn soft. If packed at this stage and a proper sirup used, it is delicious. If packed while immature, it possesses an astringent and peculiar bitter taste that is unpleasant. If it is allowed to become overripe and soft, it melts down under the process and does not have an attractive appearance. The period for proper canning is therefore short, which accounts for much of the inferior product found upon the market. The fruit is grown, hand picked, and boxed for the factory as peaches are. At some factories they are graded for size by running the fruit over screens having openings 40, 48, 56, 64, and 68 thirty-seconds of an inch in size. The apricot is not usually peeled; it is pitted and thoroughly washed, and any black spots (called soot or smut) on the surface are carefully trimmed off. The great bulk of the crop is simply split along the pit mark and left in halves, a few are peeled, and a few are sliced for a special or fancy trade.

The cans are filled by hand, the fillers using some care in separating fruit for quality after it has come to them graded for size. Fancy stock must be evenly ripened, of good color, and free from spots or defects. The underripe, soft, and badly smutted pieces are separated for seconds and water-stock. The fruit receives the appropriate sirup, is exhausted until hot, and processed for from 6 to 12 minutes.

An experiment was made to compare underripe and ripe fruit, the stock being selected from the same source and picking. The fruit which was in prime condition for canning was separated into one lot, and that which was evidently green, but which

would have been used in the factory, was separated into another lot. The treatment of the two lots was identical, a 10° sirup being used in canning. A second experiment was made to compare apricots ripened on the tree with those ripened in storage. Fruit was again selected from the same source and picking and the prime-ripe canned at once, the green being held in boxes and ripened in the laboratory. The preparation and treatment were the same as in the first experiment, but a 30° sirup was used. Both sets show very clearly a difference on the cut-out in appearance and flavor, and this is confirmed by the chemical examination. The green fruit shows in the paler and greener color greater solidity, sharper-cut edges, and pronounced acid taste. The characteristic green taste persisted in the storage ripened and was only slightly less marked than in the fresh green fruit. A difference is shown chemically in acidity and in the form in which the sugar is present. This work was duplicated in 1913 under slightly different conditions but with the same general result, showing clearly the superiority of tree-ripened over green or storage-ripened fruit.

The use of underripe stock is largely the result of the form of contract which the canner makes with the grower. It calls for the entire crop from an orchard, and at picking time the trees are stripped when the great bulk is ripe, with the result that some of those fruits which should have been left are taken. After the fruit once reaches the factory there is the same impetus to pass on. Of all the immature fruits examined the apricot is probably the most objectionable.

The apricot is decidedly acid and requires a rather heavy sirup to make it acceptable to most persons. Packing in light sirup means that the consumer must add sugar at the time of consumption, when it will require more to secure the same result than if it had been added in the can. An apricot that will not justify the use of a 20° sirup is hardly worth the canning. Apricots are also packed kettle cooked, or in the form of a heavy sauce or butter. The fruit selected for this purpose is usually soft ripe. It is rubbed through a screen to remove the skins and secure smoothness, and evaporated in a jacketed kettle until the desired consistency is obtained. Sugar may or may not be added. For a certain trade halves or slices of firm fruit are added just before the close of the cooking. This makes an excellent product, but is better known abroad than in this country.

The effect of varying densities of sirup upon the apricot is shown in the following table:

Effect of varying degrees of sirup on apricots and the "cut-out" sirup.

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
1. Moor park; weight of fruit, 480 grams; ¹ examined July 17, 1912, and Apr. 10, 1913:								
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams. per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water.....	94 ⁺	805	455	350	9.41	2.75	2.66	0.52
10.....	995	855	472	383	14.4	4.75	5.57	.80
	995	855	480	375	14.5	5.75	4.75	.81
30.....	1,020	880	450	430	25.8	6.75	14.85	.72
	1,015	875	460	415	25.3	10.50	9.02	.81
40.....	1,065	925	452	473	33.5	6.37	23.17	.67
	1,055	915	480	435	30.4	10.50	13.78	.78
50.....	1,085	945	458	487	37.0	6.25	26.07	.79
	1,085	945	455	490	35.3	13.25	16.39	.69
60.....	1,105	965	410	555	41.2	7.50	29.45	.70
	1,090	950	460	490	39.3	20.25	15.44	.73

¹ Through an error in setting the scale, the weight of fruit obtained was 480 grams, which is below commercial practice, and therefore the proportions of fruit and sirup are not quite correct, though the physical and chemical changes are properly shown.

Effect of varying degrees of sirup on apricots and the "cut-out" sirup—Continued.

Density of sirup (degrees).	Gross Weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reducing sugar.	Sucrose.	Acidity.
2. Royal apricot; weight of fruit, 550 grams; examined July 2, 29, 1913, and Jan. 20, 1914:								
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water.....	995	855	530	325	9.8	4.75	0.00	1.18
	990	850	590	260	10.2	4.75	.24	1.28
	990	850	520	330	8.7	4.74	.97	1.01
	975	835	510	325	13.6	5.00	4.75	1.26
10.....	970	830	565	265	14.4	5.00	5.70	1.27
	970	830	610	220	14.3	6.54	2.67	1.36
	1,010	870	540	330	17.8	5.00	9.26	1.19
20.....	1,010	870	555	335	17.0	5.00	8.20	1.17
	1,005	865	550	315	17.3	8.55	3.78	1.27
	1,045	905	525	380	22.5	5.25	13.30	1.18
30.....	1,040	900	535	365	22.4	6.00	12.36	1.18
	1,025	885	590	295	22.3	10.70	6.48	1.32
	1,055	915	505	410	26.8	8.50	14.73	1.13
40.....	1,055	915	585	330	26.2	8.50	12.83	1.13
	1,045	905	580	325	27.4	14.82	7.45	1.19
	1,065	925	510	415	30.0	8.50	19.47	1.11
50.....	1,065	925	540	385	30.6	9.25	16.39	1.13
	1,060	920	540	380	32.2	17.91	10.26	1.20
	1,075	935	490	445	37.3	5.00	28.50	1.04
60.....	1,070	930	510	420	35.8	7.50	23.75	1.18
	1,065	925	545	380	35.5	21.52	9.33	1.32
Ripe fruit, 10.....	980	840	465	375	14.20	4.00	7.84	.79
Green fruit, 10.....	980	840	460	380	13.40	4.75	4.99	.88
Prime ripe, 30, 560 grams.....	1,045	905	505	400	24.50	8.25	13.06	.60
Laboratory ripened, 30, 560 grams.....	1,040	900	550	350	21.80	5.50	10.92	.86

Average weight and composition of the sirup in canned apricots, and the variations above and below the average.

Grade of fruit and density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reducing sugar.	Sucrose.	Acidity.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
Extra 40° sirup:								
Average.....	1,043	903	485	418	24.1	2.86	18.06	0.65
Highest.....	1,095	955	510	445	26.8	3.75	20.66	.83
Lowest.....	1,020	880	450	390	21.4	2.25	16.39	.53
Extra standard, 30°:								
Average.....	1,023	883	465	418	20.7	3.47	13.65	.64
Highest.....	1,050	910	485	435	23.2	4.50	15.44	.73
Lowest.....	1,010	870	450	410	18.6	2.50	12.39	.52
Standard, 20°:								
Average.....	992	852	465	387	15.6	2.46	9.21	.70
Highest.....	1,045	905	570	460	17.4	3.50	10.21	1.02
Lowest.....	960	820	390	335	13.5	1.50	6.65	.53
Seconds, 10°:								
Average.....	999	859	503	356	14.1	2.44	9.90	.77
Highest.....	1,020	880	565	420	17.0	2.75	10.45	.88
Lowest.....	950	810	450	315	11.5	2.23	5.94	.58
Water-packed:								
Average.....	965	825	448	377	11.0	2.17	5.16	.61
Highest.....	1,000	860	480	400	15.3	2.75	9.03	.69
Lowest.....	945	805	410	350	8.2	1.25	2.66	.52

The apricot does not hold its form or clear-cut outline in the can as well as many other fruits. The pieces soften more or less, resulting in loss of shape and a tendency to pack together, especially if well ripened. The fill on the cut-out does not vary very much with the degree of sirup. If the can has been well filled, it should cut out about two-thirds full, though the variation between cans of the same degree of sirup may be as great as between the fill of different degrees. The waste in packing

unpeeled apricots is from 9 to 15 per cent and in the peeled about 35 per cent. The pits are dried and exported for apricot oil. The windfalls, waste from the peeling tables, and overripe stock are used for brandy.

BLACKBERRIES (*RUBUS VILLOSUS*).

The blackberry is one of the very widely distributed berries, in some sections growing wild in such profusion that no attempt is made at cultivation. The vine is very hardy and under favorable conditions is a prolific bearer. The cultivated berry has been increased in size and is of good texture and flavor. The surplus crop is canned in many parts of the United States, but it has not been developed as a special product to the extent that its quality warrants. Owing to the large yield, it should be produced at less expense than most berries, and if given the proper sirup to develop its flavor it should be received favorably by the consumer.

All berries should be collected in shallow drawers or trays and delivered promptly to the factory after being picked. It is the picking in buckets and delivering to country stores, allowing the fruit to stand for probably a day or more, and then shipping to factories in boxes in such thick layers that the bottom berries are mashed that have brought blackberries into disrepute.

On their arrival at the factory they should be hand picked to remove bits of stems, leaves, and defective fruit, and then washed in single layers under sprays of water, so that every part may be cleansed. The berries should be filled into cans by weight, the very large ones 19 to 19.5 ounces, and small ones 20 to 21 ounces. To secure this fill it may be necessary to tap the cans lightly, but not enough to mash or mar the fruit.

In experimental packing the cans were filled with 450, 500, 550, and 600 grams (16, 18, 19.6, and 21.4 ounces), and 50° sirup was used. The berries were of good size and quality. The 450-gram fill was slack and on the cut-out gave fruit which was whole and separate, but which did not occupy one-half the space after draining. The fruit in the cans with 500 grams lacked about three-fourths of an inch of coming to the top when packing. The berries remained whole and separate and occupied more than one-half the space after draining. The set having 550 grams was nearly level full and some cans needed slight tapping in order to keep the berries below the sirup. On cutting out the berries were separate, whole, and occupied two-thirds of the space. The cans filled with 600 grams of fruit required sharp tapping to cause them to settle to the level of the sirup. They were evidently overfilled for practical factory work. On exhausting, some of the berries would be forced out. The finished product showed only a slight matting at the bottom and fully three-fourths of the space was occupied after draining. With the grade of fruit used in the experiment it was evident that from 19.5 to 20 ounces made a full can.

The physical condition of the product in the can is influenced by the length of time given in processing and by cooling or not cooling after the process is completed. The fruit subjected to a short cooking and cooling usually retains a better shape and appearance; prolonged cooking or allowing the heat to be retained for a long time results in breaking it, and making more or less of a pulp. With delicate berries, however, the cooling should not be too sudden for the best results. The effect goes further than mere appearance; cooling affects the composition of the sirup, especially the quantity of sugar which will be inverted. The longer the heat is maintained the more sugar will be inverted. The difference between cooling and not cooling upon the inversion is greater than the difference in the effect of cooking for 5 or 25 minutes.

The inside lacquered can was found to be much superior to the plain tin in holding color. The loss in canning blackberries will vary from about 10 to 18 per cent on good fruit.

Effect of varying the quantity of blackberries in a can.

Weight of fruit used (grams).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
Sirup 50° Balling:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
450.....	1,035	895	367	528	32.7	13.75	15.43	0.57
500.....	1,025	890	410	475	30.5	13.63	13.79	.58
550.....	1,040	900	435	465	28.5	13.25	14.35	.57
600.....	1,022	882	477	405	25.9	11.50	12.10	.79
Commercially packed:								
Water grade.....	924	784	365	419	7.6	-----	-----	-----
Standard.....	971	831	383	448	15.0	-----	-----	-----
Extra standard..	988	848	433	415	17.4	-----	-----	-----

Effect of varying degrees of sirup on blackberries.

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
1. Mammoth; weight of fruit, 500 grams; pack of 1912; exam- ined July 17, Aug. 4, 1912, and Jan. 12, 1914:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams. per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water.....	970	830	445	385	7.3	5.75	0.24	0.45
	980	840	450	390	7.1	5.00	.00	.45
	970	830	435	295	7.3	5.16	.16	.39
	960	820	445	375	11.8	6.25	3.80	.45
10.....	970	830	450	380	12.0	6.25	2.61	.38
	965	825	430	395	12.0	7.57	2.63	.41
	1,015	875	450	425	17.7	7.50	8.31	.40
20.....	1,010	870	445	425	17.8	7.50	7.84	.42
	1,005	865	445	420	17.5	10.38	5.37	.42
	1,005	865	440	425	20.9	8.5	9.74	.39
30.....	1,015	875	440	435	22.7	8.5	10.93	.40
	1,010	870	450	420	21.2	10.63	8.70	.37
	1,050	910	450	460	24.4	9.50	9.50	.50
40.....					24.9	9.75	9.50	.47
	10.35	895	500	395	24.1	14.42	7.55	.51
	1,072	932	420	512	28.8	11.65	14.48	.54
50.....	1,077	937	450	487	31.0	14.25	12.58	.52
	1,055	915	440	475	28.4	19.91	6.05	.58
60.....	1,085	945	395	550	35.0	26.0	5.70	.44
	1,080	945	485	460	34.4	31.88	.68	.52
2. Weight of fruit used, 550 grams; pack of 1913; exam- ined June 27, Aug. 1, 1913, and Jan. 22, 1914:								
Water.....	950	810	465	345	7.0	5.25	.00	.82
	965	825	480	345	7.2	5.25	.00	.87
	960	820	470	350	7.5	4.45	.02	.93
	985	845	470	375	15.2	7.50	4.75	.92
20.....	990	850	470	380	15.2	9.25	3.32	.77
	980	840	460	380	14.8	10.20	2.06	.88
	1,000	860	445	415	19.3	8.50	8.08	.79
30.....	990	850	450	400	19.4	10.25	6.65	.75
	1,015	875	465	310	19.4	13.10	3.40	.96
	1,010	870	435	435	22.6	10.00	9.97	.77
40.....	1,040	900	465	435	23.4	10.50	9.50	.72
	1,015	875	490	385	22.7	14.51	6.10	.74
	1,045	905	395	510	28.1	10.25	14.49	.59
50.....	1,055	915	430	425	27.8	11.00	15.35	.68
	1,045	905	490	415	27.9	17.48	7.54	.74
	1,055	915	375	540	33.5	14.25	15.44	.68
60.....	1,055	915	420	395	32.4	14.25	14.96	.76
	1,070	930	480	350	33.0	23.82	7.25	.80

The effect of sirup upon the fill of the can when 550 grams were used was as follows: Berries water-packed, can lacked 1 inch of being full on the cut-out; 20° sirup, lacked 1 inch; 30° sirup, lacked 1½ inches; 40°, more than two-thirds full; 50°, about two-thirds full; and 60°, somewhat less than two-thirds full; 450 grams, one-half full; 500 grams, two-thirds full or slightly less; 550 grams, two-thirds full; and 600 grams, to within 1 inch of the top. The experimental pack for both years showed that the use of 40° and 50° sirups gave the better results, there being a slight preference for the latter. The berries preserved their identity, shape, texture, and color better than in the sirups of lower degree and were not so much shrunken or toughened as in 60°. The flavor in 40° was mildly tart and in 50° it was sweet, but both were distinctive of the fruit. The fruit packed in these sirups also stood shipping well.

CHERRIES (*PRUNUS Cerasus*).

The cherry, while largely grown for table purposes, is mainly obtained for canning and preserving in California, Oregon, New York, and Michigan. Of the several varieties used the Royal Anne is the most popular. A cherry to be well adapted for canning should have a characteristic flavor, not strongly acid, should remain whole, and not discolor in the can. It is a waste of good time and material to pack the varieties with excessive pits, which split open, producing a flat, insipid flavor.

Cherries should be delivered with the stems attached, in small or shallow boxes, as for the retail trade. They should be stemmed and washed. If they are to be graded for size, they are passed over screens having perforations of 22, 24, 26, 28, and 32 thirty-seconds of an inch. The cherry may or may not be pitted. Some prefer the unpitted fruit because of the flavor. Since the development of good pitting machines and the lessening of hand labor, however, the percentage of pitted fruit is becoming much higher. The mechanical pitters are based upon the principle of holding the cherry in a cup and thrusting a cutting plunger through it, thus forcing out the pit. They all lacerate the fruit more or less, but not more than hand pitting. For the latter a special scoop or pitting spoon is used, being inserted in the stem end to draw out the pit. A small handle bearing three wire points about an inch in length arranged in the form of a triangle just large enough to hold a pit makes a good instrument. It is forced through the cherry, driving the pit out at the stem end. The holes made in puncturing are small and scarcely noticeable after processing. After pitting, the fruit should be kept in thin layers until placed in the can. The quantity should be weighed for each can, 1 ounce more being allowed for pitted than for unpitted fruit in a No. 2 can. The sirup used should not be heavy on Royal Anne or cherries of a similar type, as a heavy sirup of 50° or 60° causes a marked shrinkage. A sirup up to 30° causes very little shrinkage and gives about all the sweetness that the product will stand without injuring the flavor. The 40° sirup causes some shrinkage in pitted fruit, but not much in whole fruit which is firm at the time of canning. In the experimental work it was found that the rate of heating had a great deal to do with the shrinkage and tenderness of the fruit. When 50° or 60° sirup, boiling, was placed on the cherries and followed with a strong three-minute exhaust, according to general practice, the shrinkage was pronounced and the fruit toughened. When the sirup was added at about 120° F. and heat gradually applied until it reached 190° F. in 30 minutes, very little shrinkage took place and the fruit remained very tender. The best results were obtained when about 45 minutes were given to the operation. Much of the splitting can be avoided by the same practice. Some packers heat their cherries in the jacketed kettle before canning, the object being to soften the fruit with heavy sirup to get a better fill. This is done to a greater extent with rather acid fruit than with the sweet. It has some advantages, but necessarily increases the labor.

Experimental lots of fruit were canned, using 400, 450, 500, 540, 560, and 600 grams in water. The weight of the fruit on the cut-out for the corresponding lots was 405, 445, 510, 530, 550, and 580 grams, there being very little change. The fill from using only 400 and 450 grams was clearly short weight; the use of 500 grams gave a slightly slack fill; and with 600 grams the can was somewhat too full. To use 540 and 560 grams required tapping of some cans, in order to get the fruit in, but, on the whole, they were easily filled. On the cut-out they lacked only a little more than one-half inch of being full after draining.

Experiments were made in canning cherries with sirups varying from 10° to 60°. The cherries were divided into three lots: Small, or those passing through a No. 26 sieve; large, those remaining above a No. 30 sieve; and a medium size which were pitted. For comparative purposes, the average of the examinations of the commercially canned article has been added to the table. The four grades which were available were extra (30° sirup), extra standard (20° sirup), standard (10° sirup), and seconds (water).

The waste consists of stems and pits. The loss in canning cherries with pits varies from about 15 to 18 per cent, and, when pitted, from 25 to 35 per cent. The loss with small cherries is much greater than with large ones, as the pits do not vary as much as the pulp. The cherry stems and pits are dried and used for flavoring in cough sirups, etc.

Effect of canning cherries in sirups of different degrees. (Royal Anne; weight of fruit used, 500 grams in No. 2½ can.)

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
	Grams.	Grams.	Grams.	Grams.	Degrees.	Grams. per 100 cc.	Grams per 100 cc.	Grams per 100 cc.
Small cherries:								
Water.....	990	850	505	345	10.60	8.00	0.00	0.42
10.....	990	850	500	350	14.6	8.25	2.14	.38
20.....	1,020	880	485	395	20.1	7.75	7.60	.39
30.....	1,030	890	470	420	24.4	10.50	10.45	.39
40.....	1,015	875	440	435	29.9	11.00	13.30	.43
50.....	1,095	955	405	550	36.0	10.75	21.61	.38
60.....	1,085	945	380	565	40.2	11.00	20.90	.38
Large cherries:								
Water.....	1,010	870	530	340	10.5	6.00	.71	.33
10.....	1,020	880	495	385	16.0	9.50	2.14	.34
20.....	1,020	880	495	385	21.3	10.50	5.70	.37
30.....	1,050	910	470	440	26.2	10.50	11.16	.33
40.....	1,060	920	440	480	31.6	10.50	16.62	.37
50.....	1,080	940	400	540	37.7	12.75	17.81	.35
60.....	1,090	950	380	570	40.5	11.00	23.75	.37
Pitted cherries:								
10.....	980	840	465	375	18.7	10.50	4.27	.32
20.....	975	835	460	375	20.5	10.50	5.46	.37
30.....	1,025	880	405	475	25.4	9.75	11.64	.39
40.....	1,045	905	440	465	31.9	12.25	14.01	.40
50.....	1,075	935	425	490	33.8	10.75	18.29	.43
60.....	1,060	920	435	485	39.2	-----	-----	.38
Average commercially canned cherries:								
Water.....	984	844	584	260	14.0	-----	-----	-----
Seconds.....	978	838	526	312	12.1	5.67	3.48	.37
Standards.....	999	859	536	322	15.8	7.81	4.57	.39
Extra standards.....	1,018	875	545	333	18.1	7.90	6.75	.37
Extra.....	1,030	890	507	383	21.5	8.00	10.4	.35
Special extra.....	1,045	905	562	343	23.7	-----	-----	-----

Effect of varying degrees of sirup on Royal Anne cherries. (Weight of fruit, 540 grams, No. 2½ can; examined July 1, 1912, Oct. 1, 1912, and Mar. 15, 1914.)

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams. per 100 cc.</i>	<i>Grams. per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water.....	1,010	870	530	340	10.5	6.00	0.71	0.33
	975	835	540	295	10.3	4.5	2.14	.34
	970	830	495	335	10.0	7.90	.00	.39
	1,020	880	495	385	16.00	9.50	2.14	.34
10.....	990	850	492	357	16.5	9.50	2.38	.33
	1,015	875	490	385	18.3	11.82	3.44	.36
20.....	1,020	880	495	385	21.3	10.50	5.70	.37
	1,045	905	505	400	21.5	10.00	6.41	.34
	1,050	910	470	440	26.2	10.5	11.16	.33
30.....	1,070	930	475	455	26.6	10.0	11.88	.33
	1,040	900	490	410	23.7	15.66	5.40	.37
	1,060	920	440	480	31.6	10.50	16.62	.37
40.....	1,070	930	445	485	32.2	12.25	14.49	.33
	1,070	930	460	470	32.2	18.92	11.32	.36
	1,080	940	410	530	36.4	13.75	19.71	.34
50.....	1,080	940	400	540	37.7	12.75	17.81	.35
	1,070	930	440	490	37.5	20.36	14.36	.36
60.....	1,090	950	380	570	40.5	11.0	23.75	.37
	1,105	965	415	550	40.6	12.5	23.28	.33

Effect of varying degrees of sirup on cherries. (Weight of fruit: Royal Anne, 550 grams; Rockport, 550 grams; Tartarian, 520 grams; examined June 2, 1913, July 2, 1913, and Jan. 17, 1914.)

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams. per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water:	975	835	535	300	10.4	6.25	0.70	0.35
Tartarian.....	975	835	525	310	9.7	6.25	.47	.32
	980	840	535	305	10.1	7.12	.21	.31
Rockport.....	970	830	550	280	8.6	4.5	.47	.19
	960	820	510	310	10.3	7.20	.10	.19
	985	845	565	280	10.3	7.0	.00	.38
Royal Anne.....	975	835	555	280	10.4	7.0	.00	.33
	975	835	560	275	10.8	7.11	.36	.31
10:								
Tartarian.....	970	830	530	300	14.6	7.5	4.27	.32
	995	855	525	330	13.6	7.75	2.85	.30
	1,000	860	530	330	13.85	7.57	3.92	.27
Rockport.....	960	820	530	290	13.6	3.75	7.12	.18
	995	855	-----	-----	14.3	6.50	5.23	.36
Royal Anne.....	995	855	-----	-----	15.3	8.50	3.09	.36
	985	845	530	315	14.2	10.00	.26	.33
20:								
Tartarian.....	1,000	860	510	350	18.0	6.0	7.36	.31
	1,005	865	510	355	18.4	7.50	5.94	.30
	1,010	870	525	345	19.1	9.50	6.61	.33
Rockport.....	985	845	525	320	19.70	2.75	14.25	.15
	990	850	525	325	17.4	8.22	6.57	.21
	1,005	865	525	340	18.5	6.5	9.26	.33
Royal Anne.....	1,005	865	510	355	18.9	8.75	7.13	.33
	1,005	865	520	345	18.2	11.74	4.03	.31
30:								
Tartarian.....	1,030	890	475	415	23.5	4.5	14.25	.30
	1,020	880	490	390	23.2	4.5	14.25	.30
	1,035	895	505	390	23.3	10.54	10.18	.26
Rockport.....	1,000	860	500	360	25.6	1.75	20.90	.13
	1,000	860	505	355	21.9	9.44	9.56	.18
	1,025	885	510	375	22.7	6.25	12.59	.34
Royal Anne.....	1,010	870	540	330	21.5	8.50	9.74	.34
	1,015	875	540	335	22.1	10.10	9.66	.32
40:								
Tartarian.....	1,030	890	425	465	28.3	4.75	18.29	.30
	1,025	885	465	420	27.2	6.50	16.39	.30
	1,035	895	485	410	28.2	13.72	12.20	.28
Rockport.....	1,015	875	475	400	30.9	3.00	23.75	.12
	1,015	875	490	385	26.8	10.08	14.59	.16
Royal Anne.....	1,030	890	495	395	26.6	8.00	14.73	.29
	1,025	885	510	375	25.7	11.32	11.82	.32

Effect of varying degrees of sirup on cherries. (Weight of fruit: Royal Anne, 550 grams; Rockport, 550 grams; Tartarian, 520 grams; examined June 2, 1913, July 2, 1913, and Jan. 17, 1914)—Continued.

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reducing sugar.	Sucrose.	Acidity.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
50:								
Tartarian.....	1,040	900	405	495	35.4	4.75	27.79	0.24
	1,050	910	415	495	32.3	6.25	21.61	.29
	1,060	920	470	450	32.25	12.13	18.06	.28
Royal Anne.....	1,040	900	415	485	33.1	6.5	23.28	.30
	1,050	910	460	450	32.9	8.50	19.95	.33
	1,040	900	490	410	31.5	13.95	.....	.32
60:								
Tartarian.....	1,040	900	385	515	40.2	3.5	30.88	.23
	1,060	920	385	535	37.4	8.00	25.65	.31
	1,055	915	450	465	36.1	12.92	20.86	.30
Royal Anne.....	1,060	920	390	530	39.6	6.0	30.67	.29
	1,065	925	415	510	37.3	7.75	25.41	.28

The cut-out appearance of a can of cherries, containing 560 grams of fruit, but packed in varying sirups, showed the following fill: Water-packed lacked one-half inch; 10° sirup, slightly more than one-half inch; 30° sirup, 1 inch; 40° sirup, 1½ inches; 50° sirup, two-thirds full; and 60° sirup, about half full. When using 400 grams and water the cans lacked 1½ inches; 450 grams, 1 inch; 500 grams, three-fourths inch; 550 grams, one-half inch; and 600 grams, one-fourth inch. In the commercially packed cherries, the extras lacked 1 inch; extra standard and standard, three-fourths inch; and seconds and water, 1½ inches of being full after draining. The practice in packing cherries has been to use from 18.5 to 19 ounces in the can. During 1913, however, most of the packers increased their weights to 20 ounces, and some to 21 and 22 ounces, many springers being produced in the latter.

CURRENTS (RIBES RUBRUM).

The currant is not canned except for stock for jelly or for mixing with other fruits to give flavor. When it is packed, it is usually put in glass or stoneware jars. It has been included in this work for comparative purposes.

Effect of varying degrees of sirup on currants. (Weight of fruit, 360 grams for a No. 2 can; examined Oct. 8, 1912, and Apr. 18, 1913.)

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reducing sugar.	Sucrose.	Acidity.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
10.....	695	595	260	335	11.6	7.75	0.47	1.14
	690	590	287	303	11.9	8.62	.12	1.23
20.....	705	605	290	315	16.2	10.75	1.66	1.42
	705	605	277	323	16.6	12.37	.00	1.26
30.....	740	640	255	385	23.4	12.00	7.36	1.07
	727	627	272	355	22.4	17.37	.60	1.21
50.....	740	640	240	400	31.8	19.00	9.02	1.18
	755	655	300	355	29.0	22.25	2.14	1.26
60.....	740	640	235	405	35.0	20.00	9.50	1.22

In all cases when the currants were unstemmed, springers and swells were produced within three months, and when stemmed the time was extended to from seven to nine months. This was not due to bacterial action. The swell was so strong as to cause the can to break in some cases. They did not pinhole as was expected. Not a single can escaped swelling and only a few were held for more than one year.

GOOSEBERRIES (RIBES GROSSULARIA).

Few gooseberries are canned, and these are largely used for pies. The berries are gathered when nearly ripe and are handled in baskets and shallow boxes. The first operation at the factory is to remove the stems and brown blossom ends. This was

done formerly by running them over a vibrating screen upon which was directed a strong blast of air. This removed part of the blossoms and stems, and the remainder were either rubbed off by hand or were passed with the fruit. An improved gooseberry cleaner consists of a slitted disk, below which parallel knives revolve. The berries are poured above the disk and made to roll over and over by light dragging chains. This causes the stem or blossom to fall into the slits, where they are cut off close to the berry. The berries are then washed and filled into cans by weight. Those intended for pies usually have only water added, while those for the general trade have a sirup. The filling, exhausting, and capping are the same as for other berries.

Effect of varying degrees of sirup on gooseberries. (Weight of fruit, 500 grams, No. 2½ can; examined June 3, 1913, July 3, 1913, and Jan. 22, 1914.)

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water.....	985	825	465	360	5.3	3.00	0.0	1.26
	965	825	465	360	5.5	3.00	.0	1.30
	960	820	505	315	5.5	2.37	.04	1.36
	1,000	860	465	395	10.2	3.00	5.22	1.17
10.....	995	855	475	380	10.4	5.00	2.38	1.30
	990	850	480	370	10.5	7.30	.57	1.39
	1,000	860	455	405	14.8	4.5	8.07	1.12
20.....	1,000	860	465	395	14.4	7.50	4.27	1.23
	1,000	860	480	380	14.7	11.18	.70	1.39
	1,000	860	450	410	21.8	7.25	8.55	1.00
30.....	1,015	875	475	400	19.6	7.50	7.84	1.26
	1,020	880	455	425	27.9	6.25	14.49	.83
40.....	1,025	885	465	420	23.9	10.00	9.50	1.26
	1,050	910	430	480	35.2	7.00	22.8	.82
50.....	1,045	905	450	455	30.0	12.50	12.83	1.26
	1,070	930	440	490	44.0	6.50	33.25	.76
60.....	1,065	925	440	485	36.5	8.75	23.61	1.22
	1,065	925	495	430	35.5	27.44	4.20	1.64

GRAPES (VITIS VINIFERA).

Grapes have not been used very extensively in canning, but there has been a noticeable increase in the pack in the last few years. The white grapes are preferred for this purpose, as the colored grapes lose color to such an extent that they become unattractive. The grapes are gathered in standard boxes or baskets as for the market. The clusters are selected when the flavor is well developed but the fruit fairly firm. The stemming is done by hand, and in California it is the general practice to grade to size by passing them over screens having holes 20, 21, 24, and 26 thirty-seconds of an inch in diameter. The fruit is washed and the cans filled to within one-fourth inch of the top and a hot sirup added. After exhausting, a process of 212° F. is given for 14 minutes.

Effect of varying degrees of sirup on grapes. (Weight of fruit, 550 grams; examined Oct. 12, 1912, Apr. 25, 1913, and Mar. 3, 1914.)

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water.....	985	845	425	420	11.3	8.25	0.00	0.54
	1,005	865	415	450	12.7	9.50	.00	.52
	1,000	860	435	425	12.5	11.18	.00	.37
	1,025	885	420	465	20.8	13.50	5.12	.31
20.....	1,022	882	412	470	21.2	15.00	2.61	.38
	1,022	882	440	442	21.3	18.28	1.75	.37
	1,042	902	407	495	23.7	12.37	9.61	.31
30.....	1,045	905	405	500	24.3	15.5	5.23	.38
	1,055	915	435	480	24.0	21.54	1.12	.37

Effect of varying the weight of fruit.

Weight of fruit (grams).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.
450.....	Grams. 900	Grams. 760	Grams. 355	Grams. 405
550.....	980	840	405	455
600.....	1,015	875	455	420

The foregoing experiments were made with Muscat grapes, and examinations of the commercial pack from these sources gave similar results.

LOGANBERRIES.

The loganberry is the result of an accidental cross of a wild blackberry and a raspberry, made by Mr. J. H. Logan at Santa Cruz, Cal., in 1881. It is grown in a very limited way in various parts of the United States, but for canning purposes only on the Pacific coast. It resembles a large blackberry in size, is red in color, and has a distinctive flavor of both the blackberry and the raspberry. It is grown and harvested in the same manner as the blackberry. It is one of the fruits that most persons find improved by cooking. It is very acid and needs a heavy sirup. Because of the limited supply and the difficulty of keeping them in the ordinary can, only a few are packed. They bleach badly and cause pin holes, with resultant spoilage. The best results are obtained with inside-laquered cans, but even these will not keep them in good condition for more than a few months.

Effect of varying degrees of sirup on loganberries and the cut-out sirup.

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reducing sugar.	Sucrose.	Acidity.
1. Weight of fruit, 360 grams; No. 2 can, examined Oct. 8, 1912, Apr. 18, 1913, and Apr. 4, 1914:	Grams.	Grams.	Grams.	Grams.	Degrees.	Grams. per 100 cc.	Grams. per 100 cc.	Grams. per 100 cc.
Water.....	667	567	287	280	6.1	3.62	0.47	1.33
	670	570	295	275	5.9	3.25	.00	1.23
	675	575	245	330	5.9	3.06	.00	1.28
10.....	680	580	300	280	12.3	8.50	1.67	1.27
	685	585	295	290	12.4	9.62	.00	1.25
	718	618	253	365	22.5	16.37	3.09	1.11
30.....	710	610	255	355	21.4	16.25	1.43	1.16
	720	620	260	360	21.6	19.28	.00	1.20
	693	593	303	290	28.6	19.66	5.35	1.26
40.....	693	593	291	302	28.0	19.94	4.51	1.26
	737	637	232	405	32.9	21.87	8.19	1.21
	735	635	241	394	32.2	23.87	3.92	1.15
50.....	740	640	255	385	32.5	29.88	.08	1.21
	750	650	237	413	37.9	23.00	11.16	1.18
	755	655	255	400	38.0	24.00	9.97	1.22
60.....	745	645	280	365	38.0	34.78	1.01	1.15
2. Weight of fruit, 550 grams; pack of 1913, examined June 17, 1913, July 18, 1913, and Jan. 25, 1914:								
Water.....	965	825	475	350	6.8	4.25	.00	1.38
	960	820	445	375	7.4	4.5	.24	1.51
	950	810	430	380	7.0	3.19	.00	1.52
	970	830	485	345	10.5	6.0	2.14	1.38
10.....	970	830	470	360	10.5	5.75	2.14	1.51
	975	835	460	375	10.8	6.41	.45	1.52
	990	850	450	400	14.4	6.5	5.28	1.38
20.....	985	845	450	395	14.2	8.75	2.14	1.49
	990	850	465	395	14.3	9.69	.76	1.60
	1,000	860	425	435	19.2	8.75	9.02	1.52
30.....	1,000	860	455	405	19.7	10.5	6.65	1.38
	995	855	455	400	19.8	14.0	1.50	1.48
	1,020	880	385	495	26.2	11.75	11.64	1.07
	1,020	880	420	460	24.6	14.75	7.13	1.47
	1,020	880	475	405	25.3	19.17	2.22	1.45
	1,015	875	375	500	30.5	11.75	16.25	1.01
50.....	1,030	890	425	465	27.7	13.75	11.64	1.39
	1,025	885	480	405	28.1	21.1	3.58	1.47
	1,040	900	380	520	36.3	13.0	19.95	.92
60.....	1,040	900	385	515	32.4	13.25	14.95	1.39
	1,040	900	465	435	31.8	24.85	3.87	1.50

The finished product is graded the same as the blackberry. The shrinkage is somewhat greater and the berries mat together more. In the experiments the fruit packed in water, 10°, 20°, and 30° sirup showed more shrinkage and softening and disintegrated more in shipping than that packed in the higher sirups. The 50° sirup gave the best results in appearance, but the 60° produced the best flavor.

PEACHES (*PRUNUS PERSICA*).

The peach is probably the most popular fruit canned, and the quantity so used is enormous. It leads all other fruits in value. The principal packing is done in California, New York, and Michigan. The conditions for growth are so favorable on the western coast, and peaches acquire such size that they are purchased on the basis of being 2½ inches or more in diameter, those below that size being received at a reduced price. The eastern packers can not make such close discrimination. A number of varieties are used, but practically all are grouped as cling, or lemon cling, and freestone. The cling is the favorite in the West, and the freestone in the East. The term "lemon cling" really refers to a nearly extinct variety, and in the future labels will read "yellow cling."

The growing, picking, and handling are the same as for the market. The picking is done by hand and should take place just when the peach is beginning to turn soft. The flavor should be clearly developed, for it will not develop after the fruit leaves the tree. The delivery to the factory is made in the standard box, and, while the necessity for prompt working is not so great as with berries, the peach, if ripe, can not safely stand for more than two or three days. In case of a rush, it may be held in cold storage for a few days, but at the sacrifice of quality.

At the factory the method of procedure depends upon the manner in which the peeling is done, whether by hand or by lye. If the lye-peeling system is used, the boxes of peaches are delivered to the pitters. As the peaches are pitted, they are placed in other boxes and there may or may not be an attempt at some grading for quality. The grading for size occurs later. It is at this point in the work that decided improvement could be made. The trucking of boxes of peaches into the factory and empty boxes and boxes of pits out is not conducive to a clean floor. The handling of the pitted peaches in numerous small boxes, while it may be clean, and in most cases is clean, is not in line with sanitary methods. Wooden boxes become foul with cut fruit and can not be easily cleaned. Trucking back and forth in the factory is not the best nor the easiest way to convey the fruit. Moreover, there is a tendency to allow some split fruit to stand for an unnecessary length of time.

The real work should begin by demanding that graded fruit be brought to the factory, or by emptying the box of peaches upon a conveyer and having a few persons remove the green and defective fruit before it reaches the pitters. The 5, 10, or 12 per cent which will not make the better grades should be taken out at the start and worked separately. This will relieve the pitters of part of their work, relieve the fillers of part of their inspection, and prevent holding up such fruit for a long time after it is split. A part of it will not be worth using, and labor all along the line will be saved. It is the first step in right grading. The objection urged is that it makes one more handling and causes bruising of fruit. A single conveyer system could easily be designed to carry the peaches to the pitters, and from the pitters to the peeling machine, thus eliminating the box system and trucking. It can be made decidedly more cleanly, and cleanliness is necessary in every step of factory work. While none of the fruit or refuse which falls upon the floor in trucking comes in contact with the fruit to be eaten, it does not look well and is conducive to carelessness in other operations. Strict cleanliness can be enforced only by making all parts clean, whether they come in contact with the food or not, and a factory can not be graded as sanitary while any part is unclean.

If the peaches be hand peeled, the fruit may or may not be graded for size first, and the subsequent conveying to the pitters and peelers may be in boxes. The difference is that the peelers have more waste to handle, but, owing to the preliminary grading, they do not have more than two pans into which to divide their fruit. The method itself makes it necessary to handle the fruit promptly to avoid discoloration. The conveying of the fruit to the pitters and of the waste and the peeled peaches to the blancher is subject to the same criticism as in the other system.

If a freestone, the peach is split around the line of the pit mark and the halves easily torn apart by a slight circular motion; if a cling, the pitting scoop is inserted close to the pit, cutting it free from one side, then scooping it out from the opposite half. The scoop is held close to the pit to avoid waste or marking the fruit. If the peach is hand-peeled, a curved knife having a guard is used, the halves being handled separately after the pitting. With a very few varieties of eastern freestones, the peeling is done by slipping the skins. This is accomplished by placing the halves, pit side down, on a tray which has been covered with cheesecloth. The cloth is then folded over the fruit and the tray placed in a steam box for about three minutes. The skin can then be lifted by picking it up at one edge. The pieces are immediately put in a can and the desired sirup added.

When hand peeling is practiced, it is the usual custom to blanch the peaches in hot water to make them more flexible for placing in the can and to remove any browning effect from the oxidase. The peaches neither gain nor lose appreciably in the blanch, as the variation on 25-pound lots by this treatment amounted to only about 4 ounces, and might be an increase or decrease. It makes it possible to pack from one-half to 1½ ounces more in a can than when blanching is not practiced. The cans are filled according to the size of the pieces, the off quality and the defective being separated for a lower grade. The sirup selected will vary according to the grade packed.

Where lye peeling is followed, the halves are passed through a machine containing a strong, hot solution of caustic soda. The amount of soda used is from 1 to 2½ pounds a gallon, strong enough to instantly cauterize the tissue with which it comes in contact. The time required for the fruit to pass through the solution is from 18 to 25 seconds, the object being to prevent the solution from penetrating the tissue. As soon as the peaches emerge they are struck with streams of water under strong pressure, which has the effect of instantly cutting off the cauterized portion. Dropping the fruit in a tank of water or under streams with weak pressure is not effective. The strong, sharp spray is very essential. The halves are next passed over grading screens having holes 64, 68, 72, and 76 thirty-seconds of an inch in size, which, with those that pass over the end, give five sizes. Automatic conveyers carry the different grades to the filling tables. The peaches are washed on the way to the grader, while they are on the grader, and are kept in water on the filling tables. By far the larger proportion of peaches are lye-peeled. Each method has its advantages and disadvantages, but in either case more depends upon the packer and the quality of the fruit used than upon the method employed.

The cans are filled by hand, the quantity being made to equal or exceed a certain number of ounces. The present method is to fill trays of one dozen cans, which are carried or trucked to the filling machine. This can easily be improved upon by the use of a conveyer. Sirup of the desired degree is added, the can exhausted for three minutes, sealed, and processed for from 12 to 20 minutes at 212° F.

The waste in canning peaches consists in pits, peels, and trimmings. The pits are dried, and in some places used for fuel, or they are shipped abroad for manufacture into oil. The table waste is sent to the brandy distillery if one be near. The waste from pits is about 16 per cent and from hand peeling about 33 to 35 per cent.

The effect of varying degrees of sirup upon peaches is not marked unless the fruit is very ripe. If overripe, the fruit breaks down and the sirup can not be drained uni-

formly. The results of experimental packing and of examinations of the commercially packed article are shown in the following tables:

Effect of varying degrees of sirup upon peaches and the "cut-out" sirup.

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
1. Weight of fruit, 560 grams; hand-peeled; pack of 1912; exam- ined Oct. 24, 1912, and May 16, 1913:								
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams. per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water.....	970	830	550	280	9.3	2.50	4.75	0.41
	965	825	520	305	8.4	3.00	1.90	.31
20.....	1,000	860	545	315	17.4	2.75	11.16	.43
	1,015	875	545	330	20.2	4.25	11.40	.35
30.....	1,025	885	545	340	20.4	6.00	10.24	.38
	1,032	892	565	327	23.9	5.00	14.96	.65
40.....	1,031	891	551	340	24.8	8.25	9.97	.50
	1,047	907	545	362	30.0	4.75	19.50	.48
50.....	1,041	901	552	349	29.3	7.89	14.84	.47
	1,057	912	517	395	33.4	5.12	21.73	.48
60.....	1,052	912	512	400	34.0	7.62	21.50	.48
2. Weight of fruit, 560 grams; lye-peeled; pack of 1913; ex- amined Aug. 12, 1913, Sept. 25, 1913, and Mar. 25, 1914:								
	955	815	535	280	8.4	3.25	2.14	.48
Water.....					8.4	3.35	2.04	.50
	975	835	525	310	9.6	3.92	2.77	.48
					11.2	3.25	4.75	.47
10.....	965	825	480	325	11.4	3.75	4.12	.44
					15.4	3.25	8.55	.42
20.....	985	845	545	300	15.0	3.75	9.02	.50
	995	855	565	290	15.9	5.82	7.13	.47
					17.4	3.25	10.45	.45
30.....	995	855	530	325	18.0	4.50	10.93	.48
	995	855	570	280	18.8	6.30	9.22	.44
					22.0	3.00	15.20	.44
40.....	1,015	875	535	340	22.4	4.25	14.72	.48
	1,020	880	565	315	21.9	7.22	11.70	.47
	1,020	980	540	340	27.8	2.50	21.85	.38
50.....					26.3	3.75	19.24	.48
	1,010	970	530	325	26.3	8.44	15.07	.44

Weight of fruit and compositions of sirup in commercially canned peaches.

Grade of fruit and density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
Extra special, 55° sirup:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
Average.....	1,034	893	494	399	26.1	4.29	17.89	0.40
Highest.....	1,075	935	585	525	32.6	5.75	24.95	.59
Lowest.....	1,000	860	410	290	21.4	3.00	11.88	.21
Extra, 40° sirup:								
Average.....	1,015	870	503	267	22.2	3.80	14.93	.43
Highest.....	1,040	900	570	420	24.0	4.74	17.57	.77
Lowest.....	990	840	440	310	19.6	2.50	12.59	.25
Extra standard, 30° sirup:								
Average.....	996	858	515	345	18.5	3.81	11.59	.40
Highest.....	1,020	880	580	410	21.8	5.75	15.91	.54
Lowest.....	980	840	440	265	17.0	2.50	8.08	.28
Standard, 20° sirup:								
Average.....	977	837	506	331	16.1	3.50	9.30	.41
Highest.....	1,000	860	625	400	19.0	5.25	11.64	.54
Lowest.....	945	805	410	220	13.3	2.75	6.65	.24
Seconds, 10° sirup:								
Average.....	958	818	516	302	12.3	2.94	6.26	.36
Highest.....	980	850	560	385	15.4	4.00	9.03	.44
Lowest.....	900	760	425	265	9.6	2.00	3.80	.27
Water:								
Average.....	947	807	514	293	9.0	2.61	4.15	.36
Highest.....	980	840	625	370	13.7	3.50	9.02	.55
Lowest.....	910	770	425	215	6.0	1.00	.95	.21

Since the peach is the most popular fruit canned, is reasonably stable, and presents an attractive appearance, it is but natural that it should be more closely graded than any other. Unfortunately, the grading is done chiefly for jobbing purposes and not for the benefit of the consumer. The appearance of the peach in the cut-out depends upon the stage of ripeness and the variety. Varieties having very large pits produce rather thin, flat pieces, though they may be large in circumference, while varieties having small pits are thick. The greener and harder the fruit, the more symmetrical the pieces and the sharper the edges. The very best fruit is inclined to become extremely tender and soften sufficiently to flatten out, to lose its clean-cut edges, and to have particles break off and become free in the sirup. Selection for the highest grades is made at the stage when the fruit does not quite soften in the handling, and when the firm, sharp edges and brilliant color give a most attractive appearance. The peach in its prime condition for canning does not undergo nearly so much shrinkage as the apricot. Most of the apparent slackness in fill is due to the softening, which allows pieces to settle together to a greater or less extent. Prime peaches packed in water, 10°, 20°, or 30° sirup will show a fill to within three-fourths of an inch of the top; in 40° sirup to about 1 inch; and in 50° or 60° sirup only slightly less. If the fruit be soft-ripe, the shrinkage will be more.

Sliced peaches are packed in the same grades as the halves, and the stock and sirup used must correspond to the same quality. Melba peaches are selected perfect peaches, packed whole. They are packed one, three, or four, the cans being made of the required height. The sirup is usually 40° or 55°. The finding of peaches which have turned pink or have sirup of a pink color is usually due to the use of sunburned fruit or to the fruit having remained hot for a long time. In neither case has the injury been found to extend further than the appearance.

PEARS (*PYRUS COMMUNIS*).

The pears used in canning may be grouped into two classes, hard and soft, the former being represented by the Kiefer and the latter by the Bartlett. Other varieties represent a very small part of the pack. The Bartlett is much the best pear for canning purposes and is probably used for nearly three-fourths of the entire pack. The pears are hand-picked just before they are ready to turn soft and are delivered to the factory in boxes of a standard size. The fruit is delivered promptly and worked up before it has time to soften sufficiently to injure the appearance in handling. If it be necessary to hold them for a week or more, they are placed in cold storage. The pears are not graded for size but are delivered to the peelers in boxes. No machine work is used in the peeling, all work being done by hand. The knife used has a curved blade, surmounted by a guard to limit the amount of peel taken off. The peel is removed from the blossom end to the stem end, instead of around the fruit, care being taken to preserve a symmetrical appearance. The fruit is then split in halves, and a special coring scoop is used to remove the blossom end, core, and stem. The matter of peeling and coring is distinctly important in the production of high-grade goods, as appearance is regarded with the same care as quality. No bruise marks, pieces cut out, or split pieces are permissible in extra standard or extra goods, and only an occasional piece in the standard. As soon as possible after peeling the pears are placed in cold water to prevent their turning brown. If it should be necessary for any reason to hold them for some time, a small quantity (about 1½ ounces to the gallon) of salt may be added, as it will lessen the action of the oxidase. The waste from pears in the form of skins and cores amounts to from 30 to 35 per cent. Only a small part is used for brandy, the remainder being discarded as waste.

The peelers make a partial separation of the pears into four sizes when they place the halves in pans, the grading being wholly by the eye. Those who fill the cans carry the work further and correct "off sizes," separating the defective and green

pieces from the better grades. The work of packing, which is wholly by hand, requires somewhat skillful adjustment of the pieces to secure full weight. All cans are weighed and packed as close to the weight selected as the size of the pieces will admit. The three grades, standards, seconds, and water, are filled without layering, which accounts in some measure for the lower weight, though anything under 500 grams in these grades should be regarded as "slack filled."

Pears, not being particularly acid or juicy, do not require a very heavy sirup. The flavor is impaired rather than improved when more than 25° sirup is used, and the higher sirups found in the special extra and extra grades are more for jobbing purposes in the trade than for real quality. After the hot sirup has been added, the cans are exhausted, then processed in an open bath for from 10 to 20 minutes.

An experiment was made to determine the effect of allowing the peeled pear to stand. In the factories it is not unusual for quantities of certain grades to accumulate and be held for an hour or more in the cans. In the experiment pears were allowed to stand one, two, three, and four hours. They were then exhausted and processed in the usual way. The effect was that some of the more delicate cells on the surface would dry out, so that after processing a more or less pitted appearance was given. The depth and size of these pits increased on standing. It was also found that during the processing a certain part of the tissue in these pits was loosened and floated in the sirup, giving a decided turbidity. This points very clearly to the necessity for rapid action in order to secure the bright, clean sirup so desirable for pears.

The color and the texture of the pear make it especially valuable in studying the effect of exhausting. A well-canned pear should have a clean, bright color, but a semitranslucent body showing quite clearly the fibro-vascular structure. The dead white or hard chalky appearance is decidedly objectionable. Properly matured pears, when given a quick, hard exhaust, which heated only the outside, retained this dead white appearance, whatever the process given. Pears given a slow exhaust at a lower temperature, but taking time for the heat to penetrate through the pieces gave the desired effect each time. High, quick heating also produced more turbidity of the sirup than longer heating at a lower temperature.

Effect of varying degrees of sirup upon pears and the "cut-out" sirup.

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
Bartlett; weight of fruit, 560 grams; ex- amined Oct. 17, 1912, Apr. 7, 1913, Apr. 2, 1914:								
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water.....	965	825	568	267	11.2	5.50	1.90	0.14
	970	830	560	270	11.0	4.75	2.13	.16
	965	825	565	260	10.8	6.14	.68	.16
	975	835	575	260	12.8	4.25	4.38	.15
10.....	980	840	560	280	14.4	4.00	5.58	.14
	975	835	560	275	13.7	6.12	4.16	.13
	995	855	568	287	16.1	4.87	6.77	.14
20.....	975	835	542	293	16.6	4.00	8.64	.13
	1,000	860	535	325	16.6	6.24	7.22	.12
	997	857	557	307	19.8	4.87	10.73	.13
30.....	990	850	545	305	20.2	4.25	11.26	.13
	1,005	865	530	335	21.5	7.28	11.15	.13
	1,020	880	565	315	24.5	5.00	15.20	.14
40.....	1,030	890	572	318	25.0	5.25	15.20	.13
	1,030	890	595	295	25.4	8.24	13.32	.12
	1,035	895	540	355	27.5	5.25	17.10	.14
50.....	1,035	895	550	345	27.0	4.50	16.86	.13
	1,050	910	555	355	27.2	7.64	16.59	.12
	1,055	915	560	355	30.8	4.75	22.56	.11
60.....	1,055	915	570	345	31.2	5.12	21.48	.14
	1,065	925			30.9	9.98	11.77	.12

Effect of varying degrees of sirup upon pears and the "cut-out" sirup—Continued.

Density of sirup (degrees).	Gross Weight.	Weight of contents.	Weight of fruit.	Weight of of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
Pack of 1913; weight of fruit, 550 grams; examined Aug. 7, 1913, Sept. 23, 1913, Feb. 4, 1914:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water ¹	950	810	580	230	9.3	5.25	0.00	0.15
Water ²	940	800	570	230	8.1	4.50	.00	.14
10.....	955	815	550	265	11.9	5.00	4.27	.14
	950	810	540	270	12.4	6.75	2.85	.16
	950	810	590	220	12.6	9.38	.21	.22
	980	840	560	280	15.2	4.50	7.60	.14
20.....	985	845	555	290	15.5	6.00	6.18	.16
	980	840	590	250	15.5	8.91	3.29	.21
	1,000	860	540	320	21.6	3.75	14.49	.13
30.....	990	850	555	295	20.6	4.5	12.11	.14
	1,000	860	565	295	21.5	6.06	12.24	.17
	1,000	860	550	310	25.5	3.25	19.47	.11
40.....	995	855	565	290	24.4	4.00	16.39	.14
	1,010	870	595	275	25.1	7.12	14.50	.16
50.....	1,015	875	485	390	30.5	3.25	23.99	.11
	1,000	860	515	345	27.9	5.25	18.76	.....

¹ Tree-ripened; tender.² Ripened in the laboratory; decidedly hard.*Average weight and composition of commercially-packed pears.*

Grade of fruit and density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of solids.	Weight of sirup.	Brix reading.	Invert sugar.	Sucrose.	Acidity.
Special extra, 40° sirup:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
Average.....	1,000	865	518	346	24.1	4.00	15.75	0.12
Highest.....	1,025	885	600	415	25.2	4.50	17.81	.13
Lowest.....	980	840	455	285	23.0	3.25	14.50	.11
Extra, 30° sirup:								
Average.....	1,009	875	531	339	17.9	4.25	10.18	.11
Highest.....	1,050	910	610	390	22.2	5.00	13.77	.15
Lowest.....	980	840	480	290	14.4	3.00	5.22	.09
Extra standard, 20° sirup:								
Average.....	982	841	531	310	16.6	4.47	8.45	.13
Highest.....	1,015	875	615	375	19.8	5.50	11.40	.15
Lowest.....	900	760	500	235	15.8	2.75	6.41	.08
Standard, 15° sirup:								
Average.....	970	829	521	306	14.3	4.00	6.91	.13
Highest.....	1,000	860	570	340	15.8	5.00	9.00	.16
Lowest.....	915	775	475	275	13.4	2.75	4.99	.09
Seconds, 10° sirup:								
Average.....	969	829	511	318	12.9	3.84	5.07	.11
Highest.....	1,000	860	545	360	14.7	4.50	7.13	.13
Lowest.....	940	800	480	280	11.2	2.75	2.85	.10
Water-packed:								
Average.....	951	811	501	311	9.3	4.25	1.99	.12
Highest.....	1,070	930	540	390	10.8	4.75	3.09	.15
Lowest.....	845	705	415	235	8.1	3.75	.43	.10

Though it may be tender, the pear has sufficient strength to maintain a very nearly normal shape and size. It is only in the heavier sirups that appreciable shrinkage occurs. It is therefore graded by the number of pieces to the can, their symmetry, texture, and color. The first three grades must be evenly matured, ripe, but not soft, and they must be nicely peeled, cored, and split equally, have good shape, fine texture, and be free from pink color. Pink pears are due to the use of imperfectly developed fruit, to fruit becoming overheated, as in a car, and to remaining hot for too long a time after processing. The difference in the condition of imperfectly developed

and overheated fruit is easily determined under the microscope. In the former case it is rare to have more than one or two pieces in a can, and then only in occasional cans. When due to prolonged heating, more pieces and cans show this defect in appearance.

PLUMS (*PRUNUS DOMESTICA*).

Several varieties of plums are used in canning, the popular ones being the green gage, the yellow egg, and the Lombard. The fruit is gathered just as it is beginning to turn soft, and the preliminary treatment is the same as for apricots. The California plums are graded for size, being run over screens having openings 32, 40, 48, and 56 thirty-seconds of an inch in diameter. They are washed, and the imperfect or spotted fruit picked out; ordinarily the plum is not peeled. The cans are then filled, some care being necessary in placing the plums so that the fill will be uniform. Hot sirup is added, and the cans processed at 212° F. for from 8 to 14 minutes.

Effect of varying degrees of sirup on green gage and yellow egg plums.

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
Green gage plums; weight of fruit, 350 grams, No. 2 can; examined Oct. 23, 1912, Apr. 11, 1913, Mar. 26, 1914:								
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water.....	695	595	328	267	8.9	4.00	1.54	0.90
	685	585	305	280	8.9	4.87	.13	.93
	690	590	390	200	9.3	5.48	.01	.91
	700	600	335	265	13.4	7.75	1.43	.94
10.....	700	600	330	270	13.7	7.87	1.54	.88
	700	600	340	260	13.3	9.20	.14	.92
	705	605	330	275	16.8	8.37	4.63	.92
20.....	707	607	335	272	16.5	10.75	1.19	.91
	690	590	340	250	16.7	12.23	.29	.92
	712	612	327	285	21.2	10.75	7.50	.93
30.....	715	615	330	285	22.4	13.00	4.63	.85
	725	625	335	290	22.1	17.38	.79	.82
	735	635	320	315	26.9	11.87	10.80	.91
40.....	730	630	320	310	27.0	17.00	5.70	.86
	730	630	350	280	26.5	22.76	.20	.91
	742	642	305	337	32.4	16.75	13.06	.83
50.....	737	637	305	332	32.8	23.75	2.14	.92
	755	655	360	290	31.8	26.25	1.13	.88
	755	655	307	348	36.6	16.51	16.51	.85
60.....	755	655	310	345	37.6	22.00	10.93	.78
	760	660	345	315	36.4	30.90	2.02	.92
Yellow egg plums; weight of fruit, 560 grams, No. 2½ can:								
Water.....	1,010	870	540	330	10.6	5.25	.00	1.24
	1,002	862	525	337	10.3	5.37	.36	1.24
	1,040	900	595	325	14.1	5.25	2.14	1.42
10.....	1,022	882	575	307	14.5	7.25	.71	1.38
	1,040	900	625	275	15.9	10.54	.00	1.37
	1,035	895	575	320	16.3	10.00	.71	1.31
20.....	1,037	897	572	325	16.2	10.5	.48	1.19
	1,035	895	600	295	16.8	11.94	.00	1.29
	1,040	900	575	325	22.0	9.75	5.94	.93
30.....	1,035	895	580	315	21.4	12.5	5.23	1.19
	1,035	895	595	300	21.9	17.90	.17	.80
40.....	1,065	925	530	395	25.5	17.75	3.56	.79
	1,050	910	570	340	25.9	22.10	.00	.88
	1,060	920	475	445	31.4	13.00	9.97	.76
50.....	1,047	907	507	400	30.2	21.75	.71	.79
	1,065	925	510	415	31.6	29.22	.00	.76
Green gage plums, 30° sirup:								
400 grams.....	982	842	335	507	24.0	12.0	8.77	.67
450 grams.....	997	857	402	455	22.5	11.2	9.03	.83
500 grams.....	1,060	920	430	490	22.8	12.5	5.22	.84
550 grams.....	1,030	890	375	575	21.0	9.0	8.82	.98

¹ Fruit, crushed, would not drain properly.

Effect of varying degrees of sirup on green gage and yellow egg plums—Continued.

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
Washington plums; weight of fruit, 550 grams; examined Aug. 6, 1913, Sept. 22, 1913, Apr. 14, 1914:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water.....	995	855	480	375	10.4	4.50	0.47	1.01
	955	845	445	400	11.7	6.5	.00	1.17
	990	850	495	355	12.6	6.70	.44	1.22
	1,000	860	440	420	14.9	5.75	4.04	.94
10.....	980	840	430	410	15.3	8.75	1.66	1.18
	970	830	500	330	16.5	9.24	1.10	1.23
20.....	1,025	885	445	440	18.6	6.00	8.55	.93
	1,030	890	425	465	18.4	8.75	5.36	1.16
	1,045	905	495	410	25.5	6.50	15.20	.76
30.....	1,035	895	505	390	23.0	10.75	8.79	1.11
	1,035	895	535	360	24.1	15.04	4.57	1.07
	1,050	910	440	470	34.0	8.25	20.90	.78
40.....	1,045	905	440	465	30.4	11.75	14.96	1.01
	1,040	900	480	420	30.5	24.60	2.09	1.09
	1,055	915	395	520	34.3	9.25	20.19	.79
50.....	1,040	900	425	475	33.2	12.75	15.44	.92
	1,050	910	490	420	32.2	23.10	4.83	1.07
	1,065	925	410	515	45.3	8.75	32.06	.69
60.....	1,060	920	430	490	36.8	15.00	18.05	.92
	1,065	925	455	470	36.0	29.28	2.66	.99

¹ Unusual variation, probably due to skins holding and not permitting the establishment of equilibrium between fruit and sirup.

Average weight of fruit and sirup in canned plums.

Grade of fruit.	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
Green gage:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water.....	955	815	480	335	11.5			
Yellow egg:								
Water.....	990	850	540	308	9.6	3.50	2.61	1.22
Green gage:								
Seconds.....	965	825	475	350	15.0			
Yellow egg:								
Seconds.....	1,002	862	470	392	12.2	7.50	1.42	1.09
Green gage:								
Standard.....	1,014	874	509	365	18.7			
Yellow egg:								
Standard.....	1,023	883	516	367	16.8	9.25	3.09	1.21
Green gage:								
Extra standard..	1,035	895	547	348	22.8			
Yellow egg:								
Extra standard..	1,015	875	500	375	18.0	14.75	3.80	1.24
Green gage:								
Extra.....	1,065	925	495	430	21.6			
Yellow egg:								
Extra.....	1,050	910	480	430	25.0	16.25	4.59	1.21

The green gage and yellow egg plums behave so nearly alike that they may be considered together. Both leave large spaces in packing and, as a result of softening from processing, settle together. If the plums are slightly green, the cut-out will appear to be somewhat better than if fully ripe, but the loss in flavor more than counterbalances the gain in appearance. The effect of sirup on the fully ripened fruit is essentially the same from water to 30° sirup, the cut-out after draining being about two-thirds full; 40° sirup reduces it to not less than two-thirds, and 50° and 60° sirup about one-half. On fruit that is slightly immature the cut-out from water to 30° sirup is within three-fourths of an inch of the top; 40°, down about 1 inch; and 50° and 60°, about 1½ inches. By weight, in 30° sirup, 400 grams give less than one-half a can; 450 grams, more than one-half; 500 grams, two-thirds; and 550 grams, three-fourths. The fruit tested was in prime condition for canning.

RASPBERRIES (*RUBUS OCCIDENTALIS* AND *R. IDAEUS*).

Raspberries are widely grown for consumption in the fresh state; very few are used for canning. They have distinctly more character than many fruits, and it would seem from the ease with which they may be grown that their use could be increased. They are grown and handled in the same manner as blackberries. The red and the black varieties are kept separate, as the red commands a higher price. The use of a sirup of the right degree is essential in bringing out the rich flavor. The process takes 12 minutes at 212° F.

Only a few experiments were made with raspberries, one part of the set being in No. 2 and one part in No. 2½ cans. The weight of fruit used in the No. 2 can was 380 grams and in the No. 2½ can 600 grams, so that the results on the cut-out are very nearly the same as if one size can had been used. The waste in canning is slightly greater than for blackberries.

Effect of varying degrees of sirup upon raspberries and the cut-out sirup (weight of fruit, 380 grams in No. 2 cans, 600 grams in No. 2½ cans; examined Oct. 10, 1912, Apr. 24, 1913, and Jan. 17, 1914).

Size of can and density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reducing sugar.	Sucrose.	Acidity.
No. 2 cans:	Grams.	Grams.	Grams.	Grams.	Degrees.	Grams per 100 cc.	Grams per 100 cc.	Grams per 100 cc.
Water.....	695	595	350	245	7.5	4.75	0.00	0.63
30.....	695	595	350	245	8.8	5.25	.00	.62
50.....	730	630	330	300	22.9	12.25	6.65	.67
60.....	715	615	330	285	21.5	12.5	5.7	.60
	735	635	310	325	29.5	12.00	13.77	.67
	730	630	315	315	29.2	12.75	12.11	.60
	735	635	325	310	32.7	12.5	15.67	.66
	725	625	315	310	32.4	13.5	14.25	.55
No. 2½ cans:								
10.....	1,008	868	567	301	13.3	8.75	1.55	.75
	990	850	590	260	13.7	8.00	1.19	.76
	1,015	875	590	285	13.2	9.88	.52	.70
20.....	1,012	872	568	304	16.5	8.12	4.82	.79
	995	855	545	310	16.7	9.50	4.27	.77
	1,005	865	560	305	17.2	12.74	1.12	.78
	1,042	902	515	387	24.3	9.00	12.23	.78
40.....	1,030	890	532	358	23.5	11.75	7.84	.73
	1,035	895	565	330	25.2	19.52	2.79	.81

Raspberries should be given a slightly heavier fill, but the same sirup as blackberries, and should give almost the same result on the cut-out. The volume in the can appears somewhat less, as the berries mat together a little closer on draining.

STRAWBERRIES (*FRAGARIA VIRGINIANA*).

Strawberries used for canning are grown the same as for the market, but only varieties of uniform size and with a well-developed flavor are used. It is preferable that they be handled in shallow boxes and drawers; in no case should boxes larger than the quart size be used.

These berries are prepared by hand at the factory, as no machine has been invented which will sort them or remove the stems. If they arrive in the shallow boxes they are stemmed, and the soft or defective ones picked out. The good berries are placed in large shallow pans, care being taken to prevent the accumulation of a layer deep enough to squeeze out any juice, then washed in a single layer under sprays. While passing under the sprays they are gently rolled over, so that all parts will be struck by the water. They are filled into the cans level with the top and the cans weighed to insure against short weight. One of the best eastern packers has the following plan: The berries are stemmed and placed directly on enameled pie plates by one set of women. These are passed to other women, who weigh out a sufficient quantity to

just fill a can, after which the berries are washed under a spray of water and then poured into the can through a special funnel. The plates are rinsed before being returned for another lot of berries. The first impression is that the method is cumbersome, but in practice it is rapid and ideal for cleanliness. The same method is also used for other berries.

The strawberry needs a good sirup to develop its flavor fully and to hold it. After a sufficient quantity of sirup to fill the can has been added, it is exhausted for 3 minutes, sealed, and processed for from 10 to 12 minutes. The practice of kettle cooking is followed by a few careful packers. The berries and sugar are placed in a copper-jacketed kettle and heated slowly to the boiling point. A special dipper is used to lift out just enough solid fruit to each can, so that the sirup may be added afterwards to make the proper fill. The object is to give a can with more solid fruit. With some packers there is a loss of fruit juice, and this is used for flavoring sirups. There is a distinct difference here in the object sought, "the full can" being the aim of some, while others strive to get all the juice out as a primary product and can the remaining solids as whole fruit. The cans are sealed at once and processed for 6 minutes. The strawberry undergoes a marked change in weight and in volume, due to the action of heat and sirup.

Effect of varying degrees of sirup upon the strawberries and the cut-out sirup.¹

Density of sirup (degrees).	Gross weight.	Weight of contents.	Weight of fruit.	Weight of sirup.	Brix reading.	Reduc- ing sugar.	Sucrose.	Acidity.
Weight of fruit, 500 grams, No. 2½ cans; pack of 1913; ex- amined Oct. 28, 1912, Apr. 23, 1914:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Degrees.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>	<i>Grams per 100 cc.</i>
Water.....	940	800	315	485	5.2	2.50	1.66	0.59
	915	775	340	435	5.4	3.25	.00	.57
10.....	940	800	310	490	9.6	7.50	4.05	.53
	940	800	310	490	9.4			
20.....	945	805	315	490	12.7	4.25	6.89	.59
	940	800	315	485	13.2	5.00	5.70	.60
30.....	960	820	325	495	18.0	4.25	11.87	.52
	985	845	360	485	19.4	11.50	6.18	.67
40.....	1,010	870	365	505	24.8	5.00	16.62	.64
	980	840	320	520	22.8	13.25	5.46	.50
50.....	1,015	875	355	520	29.4	5.50	19.47	.63
	1,025	885	360	525	29.0	12.50	10.45	.63
60.....	1,055	915	360	555	36.7	6.50	27.07	.54
	1,070	930	480	450	36.6	12.75	18.76	.59
Variety, Brandywine; weight of fruit, 500 grams; pack of 1913; examined June 2, 1913, July 2, 1913, Apr. 2, 1914:								
Water.....	910	770	320	450	6.6	4.75	.00	.52
	915	775	360	415	6.2	3.50	.00	.53
	910	770	420	350	6.5	3.86	.21	.51
10.....	940	800	300	500	10.3	8.00	.47	.63
	940	800	310	490	10.0	5.00	2.85	.58
	940	800	315	485	10.2	5.92	1.88	.49
20.....	955	815	330	485	13.9	5.00	5.94	.63
	955	815	320	495	14.7	5.50	5.94	.65
	960	820	335	485	13.9	8.94	2.64	.57
	975	835	340	495	18.6	6.25	9.50	.55
30.....	970	830	330	500	19.3	6.00	10.69	.53
	975	835	340	495	19.6	11.48	5.83	.53
	985	845	345	500	23.6	6.50	13.78	.49
40.....	990	850	340	510	24.6	8.50	13.54	.53
	980	840	360	480	24.3	22.12	.04	.55
	1,015	875	360	515	28.7	5.50	18.05	.49
50.....	1,000	860	365	495	27.8	12.00	11.88	.54
	1,005	865	350	515	29.3	27.20	.08	.53
	1,025	885	335	550	37.0	5.00	25.65	.47
60.....	1,020	880	360	520	34.7	10.00	19.95	.55
	1,010	870	375	495	34.2	26.94	5.42	.56

¹ A sufficient number of commercial samples was not received to make a fair comparative table.

The strawberry is subject to more shrinkage than any other fruit. Cans packed with 500 grams of prime fruit, using water, 10°, 20°, and 30° sirups, showed less than one-half the fill on the cut-out, and with 40°, 50°, and 60° sirups, the cans were just about one-third full.

MICROORGANISMS.

Since a great deal of attention is given to the presence of microorganisms in food products as indicating spoilage, the following table is given to show the results of examination of canned fruits made during the season. The method followed was that of using the Thoma-Zeiss counting chamber, and only the sirup or fluid portion was examined. These results have a certain value for comparative purposes and are offered for that reason. The report is in two parts, one upon the products prepared in the laboratory and one upon samples submitted from different factories. The figures in both cases are low, somewhat lower than would be obtained upon the same samples if examined six or eight months after canning, owing to the closer adherence of the organisms to the fruit when first packed.

Number of bacteria, yeasts, and spores per cubic centimeter, and the percentage of 50 fields in which mold occurred.

Product.	Number of samples.	Bacteria per cc.	Yeasts and spores per cc.	Molds in 50 fields.
Apricots:				<i>Per cent.</i>
Laboratory samples.....	17	564,000	30,000	0.00
Commercial samples.....	37	830,000	220,000	.00
Blackberries:				
Laboratory samples.....	24	151,000	364,800	.33
Commercial samples.....	10	1,440,000	492,000	1.40
Cherries:				
Laboratory samples.....	61	468,000	109,000	.00
Commercial samples.....	40	960,000	165,000	.00
Grapes:				
Laboratory samples.....	21	442,000	139,000	.00
Commercial samples.....	13	1,015,000	474,000	.00
Loganberries:				
Laboratory samples.....	12	540,000	424,000	.00
Commercial samples.....	2	1,560,000	4,410,000	3.00
Currents, laboratory samples.....	9	399,840	279,960	.60
Peaches:				
Laboratory samples.....	17	670,200	56,400	.10
Commercial samples.....	96	984,000	189,960	.06
Pears:				
Laboratory samples.....	15	480,000	99,600	.00
Commercial samples.....	65	1,084,800	192,760	.03
Plums:				
Laboratory samples.....	39	276,000	67,680	.00
Commercial samples.....	26	544,560	150,000	.15
Raspberries, laboratory samples.....	17	280,000	194,000	.17
Strawberries, laboratory samples.....	31	387,120	106,440	.50
Tomatoes, laboratory samples.....	43	19,872,000	1,354,800	7.58
Apples, laboratory samples.....	5	159,840	9,996	.00

VEGETABLES.

The distinctive feature in the canning of vegetables is that they require heavier processing than fruits, and for sterilization need a higher temperature, or longer time, or both. Another feature is the substitution of mechanical methods for hand labor. Fruits require a large amount of hand labor in the preparation and in the filling of the cans, while with the majority of vegetables almost every step can be accomplished by a machine.

ASPARAGUS (*ASPARAGUS OFFICINALIS*).

The packing of asparagus had its beginning in this country at Hunter's Point, Long Island, now within the confines of greater New York City. The first packer was

William H. Hudson, who put up about 400 dozen tins in 1864. The package used was almost identical with the No. 3 square can of to-day. The preliminary treatment in the way of cutting and blanching was also very similar to that now used. The processing was different, for the cans were first held in a bath for 30 minutes, then vented, and afterward held for an hour and a half in a bath of boiling water. The industry grew fairly rapidly in New York and New Jersey, but has almost ceased since California became a producer in the early nineties. The real packing of asparagus in California was established by Mr. Hickmott, who began experiments in 1881 but was not very successful until 1890. The distinctive feature of his method was the erection of the cannery very near the asparagus beds, so that the product might be collected and delivered in a perfectly fresh state, as the holding of the product for even a short time greatly impairs the flavor.

The asparagus produced on the western coast has the advantage of unusual natural conditions for growth, as the beds are in the delta lands along the Sacramento and San Joaquin Rivers. The soil is of wonderful fertility, light and mellow, so that it may be hilled high to produce long, large stalks. The spring is cool, insuring growth that is not too rapid, each spear being succulent and tender. The stalks are naturally bleached so that they are very white. Even food officials have believed the canned article to be chemically treated to obtain the very pale color.

Asparagus is a costly product, because it can be grown only upon very valuable land and a great amount of hand labor is required. The growing is the same as for the market, only the beds cover hundreds of acres. The plants are set close together in rows 4 feet apart. Three years are required to bring them to a productive state. When the plants have stooled sufficiently to permit the removal of a part of the stalks for consumption, the rows are covered over with soil to a depth of a foot or more. These are kept hilled up in the spring and free from all weeds. This great depth forces the new stalk to grow about 1 foot to reach the light, and, as no color is formed until light reaches the tip, the stalk is perfectly pale or white. The harvesters pass between the rows looking for a spear wherever they see the ground cracked or broken. When found, a cutter very much like a carpenter's chisel is inserted at such an angle as to cut the stalk about 9 inches below the surface. The stalk is drawn from the ground carefully so that the top may not be marred nor snapped off. Only one stalk can be cut at a time and the cutting must be done every day or every other day. The cutters carry the stalks in baskets to convenient points and empty them between the rows. A man with a small sled follows closely behind the cutters, picks up the "grass," and cords it on the sled, keeping all tips in one direction. It is next hauled to some convenient point in the field where water is available. There the "grass" is picked off the sled and placed in a frame, the tips all turned in one direction against a smooth board wall. This frame is from 1 foot to 2 feet in height and from 6 to 8 feet long. When it is filled, a board is pressed on top of the grass, and by using this and the bottom as guides all stalks are cut to a uniform length of 7½ inches. All the stalk in excess of this length is waste. The next step is to dump the cut grass into a tank of water to wash off adherent grit. It is absolutely necessary that this washing should be done before any drying takes place, for with the drying a certain amount of staining develops, and this can not be removed by any subsequent treatment.

The stalks are picked out of the water by hand, again arranged with tips in one direction, and corded in crates in two rows, the tips being kept to the center. The boxes are hauled to the factory promptly, so that the asparagus can be used within a few hours, thus avoiding all possibility of wilting. At all the better canneries work upon the grass is begun within three hours from the time it is cut and stock is not carried over from one day to the next.

At the factory the first operation is to empty the crate upon a sorting table, where the stalks are sorted into five grades, based on size, and into two qualities, dependent upon whether the stalks are wholly blanched or partially green. They are further

sorted, separating the straight stems from the crooked. All the sorting is done by hand. The five grades for size, based upon the number of stalks which will go into a standard No. 2½ square can, are known as giant, mammoth, large, medium, and small. With giant stalks about 14 are required; mammoth, 20 to 22; large, 30 to 33; medium, 40; and small, 50. What are known as asparagus tips are put up in cans just one-half the regular size, about 30 per cent more stalks being required to fill the can. The so-called hotel tips are the cuttings made in trimming the asparagus to size and the whole stalks which are crooked or deformed. These are just as good as the other, though not so pleasing in appearance. Some of the large asparagus is peeled, or stripped, as the operation is more properly called.

After grading the stalks they are again cut to length for the different sizes of cans used; 5½ inches for the regular square can; 4 inches for the No. 1 tall and No. 2; and 3 inches for tips. The loss of weight in preparation for tall cans after the asparagus reaches the factory is about 16½ per cent for No. 1 tall; for No. 2, about 40 per cent; and for tips, 60 per cent. The part cut off represents waste at the present time, as only a very small part of this is used as soup stock. After grading and cutting the stalks to length, they are blanched until they are just softened through, so that they are flexible but will not snap off on bending. The time required is from 30 seconds to 3 or 4 inches, depending upon the size and age of the material. Then follows heavy spraying in cold water, and again each spear must be hand-sorted for color, the pure white and that tipped with green. They are then filled into cans, always keeping the tips up. The can must be crowded, for there will be some shrinkage after processing; if the can is not well filled it will not ship well, and the ends and side buds will be knocked off, giving an unattractive appearance. The interspaces are filled with brine testing about 8° Balling (about 6½ ounces of salt per gallon of water). The process takes from 12 to 22 minutes at 240° F., and the cans are cooled at once.

The asparagus tip was first packed to use the stalks which might be cut somewhat short or be broken, then to care for the tender ends which might be left when the grass was delayed in transit to the cannery or forced to stand overnight. Now they are packed as a regular product, as they are held in high esteem by the consumers. It requires nearly 20 per cent more tips to make a can than when the whole stalk is used, which necessitates a higher proportionate cost. The enormous loss in trimming the stalks to the required length and the hand labor involved in every operation make the cost of asparagus necessarily high, and, while a large part of the work might be simplified, cost can not be materially reduced.

Some experiments were conducted in canning asparagus to note the effect of standing. One lot was packed within 3 hours after cutting, a second lot within 24 hours, a third within 48 hours, a fourth within 72 hours, and a fifth within 96 hours. Each lot consisted of two parts of about 20 cans each, one part being filled with long or full-length stalks, and the other with tips.

The lot put up immediately on arriving at the factory was perfectly tender from the tip to the base in every stalk. It had a bright, clean, crisp appearance.

The lot put up within 24 hours lacked some of the clean luster characteristic of the fresh, the tips were all tender and gave no evidence of unnatural flavor. The full-length spears were excellent at the tip, but more than 30 per cent were a little fibrous at the butt and had the beginning of a bitter flavor.

The lot held for 48 hours showed more dulling in color, the beginning of a yellow cast, and a little wrinkling of the stalks as though they were shrinking. The tips were good, with only the beginning of toughening at the base and some bitter taste. In the full stalks the base was decidedly fibrous for nearly one-half its length and had a decidedly bitter taste at the butt, becoming less marked as one approached the tip. About one-half the stalk was edible.

The lot held for 72 hours showed similar changes in a still more marked degree, more yellowing, more furrowing or wrinkling of the stalks, decidedly more fibrous

material, and the development of a strong bitter flavor, more marked at the base and extending within about $1\frac{1}{2}$ inches of the tips. The full-length stalks were not edible, but the tips might pass for a low grade.

The lot held for 96 hours had a poor, sickly yellowish-green cast, and was decidedly wrinkled and very tough and bitter throughout its entire length. It was not edible, the bitter principle being strongly developed. This asparagus was kept in a moderately cool place, but had no water turned on to keep it moist. It was not subjected to unusual drying. The loss in weight per hundred the first day was about 4 pounds, and the most of this was probably from water which had been held between the stalks after the field washing. On the succeeding days the loss was only from 1 to 2 pounds per hundred. The shrunken appearance after 72 hours gave the impression of a much greater loss in weight.

Experiments were also made with the use of lacquered cans, and while the results were interesting they have not shown an improvement from any standpoint. The most important advance made during the year has been the perfection of the square open-topped can. The round can is objectionable because it permits the contents to roll when being handled or in transit and breaks off the top and side buds, injuring the appearance of the stalk and liquor.

BEANS, GREEN (*PHASEOLUS NANUS*).

String beans form a regular side dish at almost every hotel, and they are generally the canned article. There is a large pack of beans each year, and while hotels and restaurants were formerly the principal buyers a large demand for home use has been created in the past few years. The beans raised for canning are produced in the same way as for the market. The growth is best when the season is fairly moist and cool, the majority of the beans being produced in northern New York and Michigan. More recently large packs have been put up in Wisconsin.

The beans are picked by hand. They are gathered as young as possible. The best are about $2\frac{1}{2}$ inches long and less than a fourth of an inch in thickness; the large beans become tough and stringy. At the factory the beans are graded in five sizes by means of special machinery, the essential feature of which is a series of vibrating screens made of rods or bars running in one direction. These rods are generally set 18, 14, 11, and 8 sixty-fourths of an inch apart. The beans are fed in over the coarser screen first and those which fail to pass through constitute one grade. As the beans pass to each succeeding screen the next size is separated, and the smallest pass through last. The work is done better than it was formerly done by hand.

The next step is to snip or string the beans. Some varieties of beans are so nearly stringless that the simple snipping of the ends is sufficient, but when they become old, hand stringing is necessary. The cutting of the ends, or snipping as it is called, can be done well by machinery. It is also the practice to cut the large beans in lengths of about 1 inch. All beans are well washed, placed in wire baskets, and blanched, or they may be blanched in the cylinders used for peas. The time required for blanching will vary with the age; the small-size young beans will require only about $1\frac{1}{2}$ minutes, the larger ones if tender will require about 4 minutes, and if hard and tough they may require 8 or 9 minutes. It is the rule of good processors to blanch until the beans are tender, irrespective of time, and for that reason many prefer the basket in a tank of boiling water to the pea blancher.

The blanched beans are filled into the can by means of a special bean filler. This machine carries a tray, holding 4 dozen cans, and has a hopper above it with holes corresponding to each can. The beans are poured into the hopper, the quick vibrating motion of which shakes the beans into the can. As a further precaution against short weight, each can is weighed and any deficiency in fill is made up by hand. A weak hot salt brine is used to fill the interspaces in the cans, which are exhausted, capped, and processed for 30 minutes at 240° F., as for peas. A full can should weigh not less than 13 ounces, exclusive of the liquor.

BEANS, LIMA (*PHASEOLUS LUNATUS*).

Lima beans are grown for canning both as a green bean and as the bean in succotash. There are two varieties, the pale or true Lima and the bush variety. The former is but little grown for canning, as it must be gathered by hand the same as string beans, while in the case of the bush beans the whole vine is taken up and hauled to the factory, as in the case of pea vines, and then run through a pea viner to shell the beans. The speed of the viner is changed to meet the altered conditions. The beans are graded generally into four sizes, if canned, but are left ungraded if intended for succotash. It is also becoming the custom, as with peas, to can some beans ungraded. A better flavor seems to result from the combination than is obtained when they are canned separately. The sizes are as follows, and are obtained by sifting over the screens with openings 24, 30, 31, and 32 thirty-seconds of an inch. Those passing through the first screen are called tiny; through the second screen, fancy; through the third screen, medium; through the fourth, standard. Those passing over the last screen are sometimes designated large or mammoth beans. The beans are blanched as peas are, and the can is filled so that after processing it will be full and just covered with brine. The process is the same as for peas. A full can should weigh not less than 13 ounces, exclusive of the liquor.

BEANS, WAX.

Wax beans are handled in the same way as string beans. More attention, however, is paid to sorting, as any spot will show on the light surface. The weight of the beans in the can should not be less than 10 ounces, exclusive of the liquor.

BEETS (*BETA VULGARIS*).

Beets grown for canning must be of a deep-red variety, evenly colored throughout. Pale or uneven-colored beets present a very poor appearance in the can. The beets used for canning are mostly grown in New York, and are cultivated as in the garden, but in large acreage. The tops are cut off and they are hauled to the factory as tomatoes are. The time of packing is in the fall, usually the latter part of September.

At the factory the beets are graded into four sizes—small, sometimes called rosebud, the beet being less than 1 inch in diameter; medium, the beets being from 1 to 1½ inches in diameter; large, those from 1½ to 2 inches; and very large, those over 2 inches. The very large beets must be cut into pieces for canning, and for that reason are called cut beets. The grading is done in a wooden squirrel cage having the slats set at proper distances or over tables having holes of the size indicated.

After being graded the beets are soaked in tanks of water to soften the adherent dirt and are then sprayed well. The beets are next placed in large iron crates or heavy iron baskets, placed in the retort, and steamed for 20 minutes at 220° F. This loosens the skin so that they may be peeled with the best possible results. The peeling is done by hand, as is also the filling of the cans. Only water is used on the beets, though salt may be added at the rate of a teaspoonful to the can; enamel cans should be used, otherwise the beets will be discolored. The process on beets is 245° F. for 1 hour.

CORN, SWEET (*ZEA MAYS*).

Canned corn is the result of the persistence of Isaac Winslow, of Maine. He was a sailor by occupation. In his wanderings upon the high seas he visited France and learned the method of preserving food by canning. The advantage of such foods, particularly to sailors, was obvious. Mr. Winslow began experimenting on the canning of corn in 1839, the first trials consisting in boiling the corn on the kitchen stove for varying periods of time. The cans were marked and a record kept of each lot. The results were mostly failures, but a sufficient number of cans were saved, and these were of such good quality that the efforts were continued. The succeeding years gave

essentially the same result. In 1843 he built a small boiler to generate steam and a wooden box in which to put the cans, so that the cooking might be done in a closed steam chamber. As the results were less successful than in the previous years, the steam box was discarded. It was not until 1853 that he had sufficient success to warrant applying for a patent on his method, and it was regarded with so much distrust that the letters were not granted until 1862. Winslow first packed the corn on the cob, but this was bulky, and he believed that the cob absorbed some of the sweetness. He next pulled the kernels off the cob with a fork, and finally cut the corn with a case knife. Winslow's apparatus and methods were crude, but he discovered the principles which underlie the canning of corn. It may also be said that he and his successors brought fame to Maine corn as a canned product, and this reputation persists to the present time.

The canning of corn is a large industry in Maine and other States extending from New York to Maryland, west to Iowa, and north to Minnesota. In most of the Eastern States the crop is grown by numerous farmers in small patches of a few acres, while several of the western factories raise their own corn, covering hundreds of acres. At Hoopeston, Ill., two canneries use the product of 7,500 acres. Claims are made that certain sections produce better and sweeter corn than others. This is not always sustained by facts, for quality is also affected by the variety and state of maturity when gathered. Again, some canners pay more attention to the quantity of corn grown on an acre than to the quality. The seed used is grown by specialists, as a rule, and a very large part of it comes from Connecticut, a State in which no canning of corn is done. The type of corn used now is quite different from that canned several years ago. The effort is to develop a tender, fine-flavored sweet corn. The ears are of two types, those having large, flat kernels arranged in rows and those with small, long kernels irregularly placed. Stowell's Evergreen is typical of the former type and Country Gentleman of the latter. The corn is planted and cultivated in the same way as field corn, and is gathered by snapping off the ear when it is in its prime. The ears are hauled to the factory in the husk in order to protect the kernels from injury in handling and from dirt and exposure.

A modern corn-canning plant is a large establishment, equipped with valuable automatic machinery to do the work in a rapid, cleanly manner. When the corn arrives at the factory it is dumped from the wagon onto a conveyer, which carries the ears to different parts of the husking shed as they are needed. Most of the husking is done by hand, but this practice will undoubtedly give way to machine methods, as the husking machines have been almost perfected in recent years. As rapidly as a bushel measure is husked it is put upon a conveyer, and while on the way to the silking machine is sorted for quality. A high grade may be secured only by selecting ears with grains which are uniformly tender. Corn which is too old or too young to make a fancy grade of goods is taken out and held until a sufficient quantity accumulates to make a run on a lower grade. The silking is done by means of rolls and brushes. As the ear revolves on its axis and at the same time is carried forward, it is gently wiped by rapidly revolving brushes, which pick up any silk that may be attached. This work is done with remarkable rapidity and by machinery so carefully adjusted for any irregularity in the size of the ears or even in a single ear that there is no chafing or bruising of the tenderest grains. This process is immediately followed at some factories by a thorough spraying with water, while at others this is omitted, the claim being made that a certain flavor is lost.

The corn is cut by machinery, and from the time the ear is fed into the cutter until the corn is sealed in the can it is not again touched by hand. The ear is forced through a series of curved knives, mounted in an adjustable circular frame, so that they will accommodate themselves to the varying size of the cob. Scrapers complete the work by removing the grain and soft bits of kernel at the base. The corn again passes through a machine to remove bits of silk, husk, or cob, so that the final product is as

clean as machinery can make it. This cleaner consists of a series of wire combs, which intermesh as the corn passes through, and wire cylinders which act as sifters.

The corn is next mixed and cooked, and in this operation it is necessary to add some water, otherwise it would become a dry, tough mass in the can. The quantity of water used will depend upon the consistency desired and the condition of the corn. Some varieties require more than others, but the average quantity used in cream corn is about 5 ounces per can. It is also usual to add both salt and sugar to the corn to give the desired flavor. This is used in all grades, though more carefully in the high grades than in the low. The eastern packers, as a rule, use more sugar than the western.

The care with which the cooking is done before the corn enters the can determines in a large measure its appearance. Too much brine will give a sloppy can, while too little gives a dry can. Insufficient cooking will leave the brine and corn separated; the quantity of brine may be right but the corn may be dry in the bottom of the can and most of the brine on top, or they may be mixed but not blended. The preliminary heating is done by steam, using automatic machinery, which heats and evenly mixes the corn and brine and at the same time fills the cans. The corn enters the cans at about 180° F., and the capping is done in the usual manner.

Corn is one of the most difficult products to process. It requires a temperature of about 250° F. for 75 minutes to insure sterilization. There are packers who process at from 240° to 245° for 90 minutes, and others who process their corn twice to insure keeping. The higher the temperature the browner the corn and the more pronounced the cooked taste. The consistency of the corn makes a great difference in the heat which must be used; the drier the corn the slower the heat penetration.

Corn is packed as "cream corn," or, as it is sometimes called, "Maine style," the kernels being cut as already described and the portion scraped from the cob added. The product should be of a thick, creamy consistency. Again, the corn is cut from the cob as closely as possible by knives, but only the whole grains are used, the bits and scrapings being discarded; corn used in this way must have long, slender grains, commonly called "shoe peg," and the quantity of brine be such as to keep the kernels separate. This method of preparation is called "Maryland style" by the trade. In some instances the corn is run through a recutter, which gives a grainy effect or one like the cream corn, depending upon the method of handling. This procedure is also followed in working up corn which has become too old to make a good regular pack. Corn may be run through slitting machines, which cut the grains open on the end and then squeeze out the contents, leaving it free from hull. Cut corn is also run through a "cyclone," a machine for forcing the creamy portion of the kernel through a fine sieve, thus removing all of the hull and giving much the appearance of green corn meal.

Field corn is not used in canning. Some of the sweet corn used produces very large ears and coarse grains, which give rise to the suspicion that field corn has been substituted. There has been a very general improvement in sweet corn in the last 10 years, and it will probably not be long before this coarser variety will give way to a better and sweeter one.

A can of fancy corn when opened should be well filled (within three-eighths of an inch of the top), should be absolutely young and tender stock, medium moist, practically free from silk or bits of cob or husk, only slightly darker than natural or of a light golden-brown color, and have the distinctive young corn flavor. The weight of the contents should be about 21 ounces. If put up in "Maryland style," the kernels should be separate and the brine nearly clear and the corn should weigh not less than 13.5 ounces, exclusive of the liquor.

A can of standard corn should be well filled, reasonably tender, fairly bright color or slightly brown, and nearly free from silk, bits of cob, or husk. The flavor should be characteristic of young sweet corn. If put up in "Maryland style," a part of the kernels may be somewhat hardened and the brine a little cloudy.

PEAS (*PISUM SATIVUM*).

The transition from the custom of growing a small patch of peas in the garden to supply a few meals of a choice vegetable during the growing season to that of growing hundreds of acres to supply a canning factory packing an article available at all seasons is but an incident in the development of a great industry. The garden bed was spaded, raked, and planted by hand. Brush was obtained from the orchard or wood lot, and the rows "stuck" in order to insure the vines proper support. When the green peas were picked and carefully prepared, they made what was at one time styled a dainty dish. The fields are now cultivated, sowed, and the crop harvested by machinery the same as any farm crop. There are several factories which take the entire yield from more than 1,000 acres. The plants selected have sufficient rigidity, no added support being necessary. The whole plant is hauled to the factory while fresh and green, the same as a load of hay.

The canning of peas dates back to the beginning of canning. Peas are one of the three large crops packed. In this country the packing of peas is confined largely to those States having a cool spring and plentiful rainfall. The southern limit of successful growing seems to be from Maryland west to Indiana and northwest to Minnesota. Some peas are also grown on the highlands in Colorado and a few on the western coast. Wisconsin, Michigan, New York, and Indiana lead in this crop.

The pea used for canning belongs to the garden variety, *Pisum sativum*, of which there are two general classes, the early, or round smooth pea, and the wrinkled pea. The latter is much the sweeter. The Little Gem and Alaska are typical of the first class, and Horseford's Market Garden, Admiral, and Advancers of the second.

The peas are generally sown upon good ground, well prepared, as early in the spring as frost will permit, and no subsequent cultivation given (except in California). Instead of all being sown at one time, the seeding is made to extend over several weeks, in order to prevent too many maturing at one time. When the peas are well grown and are still very tender, they are cut by mowing machines or special pea harvesters, and are then loaded upon wagons and hauled to the factory. Until a few years ago, the pods were picked from the vines in the field and taken to the factory in baskets or bags. This necessitated a very large force of men, women, and children in harvesting, and added much to the cost of the product. There are only a few factories in the United States which follow this method at the present time, and it is limited to a part of the pack.

The vining machine, which is used for separating the peas from the pods while they are still on the vine, is a very simple and ingenious device to accomplish a difficult task—the shelling of the tender pea so carefully that it will not be injured. It consists of a large cylinder, perforated with many holes, which are large enough to permit the peas to pass through, but not the vine. Within the cylinder is a heavy shaft, bearing strong paddles or beaters. The cylinder is made to revolve rather slowly and the beaters very rapidly, in the opposite direction. The vines are fed in at one end of the cylinder, are carried upward by its motion, and fall upon the beaters, which strike the pods, causing them to burst open and discharge the peas. The peas roll out through the holes in the cylinder, and the vines pass out the opposite end. The present vining machine is a modification of the podding machine which was invented by Madam Faure. It was the first important step in the development of the pea-canning industry.

The next step in the process is that of cleaning, which consists of two operations; first, passing the peas through a fanning mill to remove pieces of pods, leaves, and dirt, and, second, washing, which is done in wire cylinders known as squirrel cages. These cylinders are set on a slight incline and made to revolve slowly, so that peas which enter at one end gradually roll out at the opposite end, and while doing so they are well sprayed with pure cold water. After the washing, the peas are graded for size. This is done by passing them over vibrating screens, which have holes of a

definite size, or through cylinders, with sections having perforations corresponding to those in the screens. The perforations are standard and give the following sizes in the peas: *Petits pois*, extra sifted, sifted, early June, marrowfat, and, in the case of late peas, the telephone. If the peas are properly labeled, they should be uniform in size. Some manufacturers, instead of turning out all these sizes, combine two sizes in one. A few peas are sold ungraded or with only the first and second size taken out. The *petits pois* should pass through an 18 sixty-fourths inch hole; the extra sifted, or extra fine, through a 20 sixty-fourths inch hole; the sifted, or fine, through a 22 sixty-fourths inch hole; early June, through a 24 sixty-fourths inch hole; while the marrowfats pass over the ends of the screens. With sweet wrinkled peas, a 26 sixty-fourths inch screen is used to separate the marrowfats, and those remaining above pass over as telephone size. These designations, which were partially adopted from the French, have been in use for a long time, and refer to size and not to variety nor to time of gathering, as would be inferred from the name "early June." The term "early June" has, in recent years, come to have another meaning, that of including all of the smooth or Alaska group of peas in distinction from the sweet wrinkled varieties. We therefore find smallest-sifted early June, extra-sifted early June, and sifted early June, as distinguished from the same names applied to sweets. The trade terms have little meaning to the consumer and could be supplanted by proper descriptive terms to the advantage of all concerned.

Peas are also graded for quality. Those that are small, young, and tender, so that they will crush easily between the thumb and finger, are considered to be the highest grade, while those that have a considerable percentage hard, turn brown upon processing, or cause clouded liquor in the can are of a lower grade. The grading is done largely upon the judgment of the inspector as the peas arrive, and later by the superintendent.

The peas may be mechanically graded for quality before, but preferably after, grading for size. This is possible because the old or hard peas are heavier than the younger and more tender ones. As peas will not all mature alike on the same vine, nor in the same field, it is not possible to cut them so as to secure absolute uniformity. The more slowly the peas mature, under fairly cool moist conditions, the tenderer they will be, so that in some sections the necessity for grading for quality is less than in others. This grading is effected by means of brine, which is made to a strength that will float those that are tender, the harder ones sinking. The first quality can be skimmed off, and those that sink can be again separated in another and heavier solution, giving a second and third grade. The first grade will be lighter in color and softer on pressure, and will give a clear liquor on canning; the second grade will be slightly darker, and the liquor cloudy; while in the third grade the size will be uneven, the peas dark and hard, and the liquor very cloudy and thick. In dry seasons the grading will not be so good, as there is less difference in the weight of the peas. It is possible to get 15 grades of peas, depending upon size and quality, from the same load, the difference being sufficient to be easily distinguishable in the finished product.

When the peas leave the graders they pass over slowly moving belts in a single layer, and those which are split, off color, or defective are picked out. This is the only operation in which it is necessary to touch the peas with the hands.

The peas are blanched, or more properly parboiled. They are boiled just long enough to soften them uniformly and to remove the mucous substance on the outside. The time for the blanching will vary from one-half minute for the very tender small peas to 15 minutes for the overmatured large ones, some variation being necessary for each size and degree of hardness. Most of the blanching requires from 1 to 4 minutes.

The matter of blanching is exceedingly important, for upon it depends in a large degree the appearance of the peas and the character of the liquor. There are several different styles of apparatus in use for blanching, the simplest being a large trough containing scalding water in which wire baskets holding the peas are placed for the re-

quired time. Another device consists of a cylinder which is made to revolve in a tank of water and gradually cause the peas to pass through in a continuous stream by means of a large screwlike conveyer. The latest type is a tank having three compartments; the peas are fed in at one end and the hot water at the other, so that the water in which the peas are first scalded is being constantly renewed from the next tank, and, as the peas emerge, they come from the freshest, cleanest bath. The peas are again washed after blanching and before going to the filling machines.

The pea fillers should measure out a given quantity of peas and deliver them into the can with the minimum of cutting or bruising. The greater the number of injured peas the less attractive the contents, both because of splits and because of cloudy liquor. The fillers should be adjustable, that the cans may receive a fill according to size and age. The younger and smaller the peas the greater the fill, and vice versa. Old peas absorb liquor in the process, while the succulent ones take up very little. The liquor used in canning peas is made up of water, salt, and sugar, the proportions being a matter of taste. The eastern packers, as a rule, use more seasoning than the western. The liquor is added after the peas have been put in the can. The subsequent capping and processing is the same as for corn. The process is from 235° to 240° F. for from 35 to 40 minutes, depending upon the freshness and state of maturity. The cans of peas should be immersed in a cold bath at once after the process is finished, in order to arrest cooking and insure a clear liquor.

The canning of peas requires special care. If a fine product is to be secured, there must be careful selection in the field and continuous and rapid work from start to finish after the vines are cut. "Only an hour from the field to the can" is not literally true, but it is approximately so. The work is almost wholly done by automatic machinery connected by special conveyers in such manner as to insure continuous action. At all the various steps the washing is of the most thorough character, and in some of the best factories almost a gallon of water is used in the preparation of each can. American peas of the highest grade represent the best that is accomplished in the canning industry, and are unexcelled by any foreign production.

The cost of a can of peas will vary with the size and quality. The very tender smallest sifting peas, or "petits pois," are the most expensive for the reason that but comparatively few are produced; not more than 5 per cent of a good crop will be of that grade. The price gradually decreases through the sizes to the marrowfat, which is the cheapest. There is more nutrition in the larger sizes, and, if properly graded, they have the better flavor. Ungraded peas have a particularly good flavor, though they are not so attractive because of lack of uniformity.

A well-filled No. 2 can of peas should have a net weight of about 21 ounces, of which slightly more than 13 ounces should be peas and 7 ounces liquor.

First-grade peas should be from selected field stock, or the lightest weight if separated, and the can should be well filled with peas that are uniform and true to the size indicated, even in color, absolutely tender, of good flavor, and covered with a clear liquor. The weight of the peas, exclusive of the liquor, should be not less than 12 ounces.

A can of standard peas should be well filled with good field-run stock, the peas fairly uniform, of the size indicated, and covered with liquor, which may be more or less cloudy but not thick. There may be some variation in color, but the peas should be tender, or only a small proportion hard, and of good flavor.

PUMPKIN (*CUCURBITA PEPO* L.).

It used to be the custom to associate pumpkin pie with the Thanksgiving season, but the tin can has lengthened its season to the full year, and made it especially convenient for the home pie-maker.

The pumpkins used for canning should be of a hard, sweet variety, and evenly ripened. The meat should be of good texture, golden yellow, but not watery. It has

been the custom generally to grow the pumpkins with the corn, but a few canners find that a more satisfactory yield and a far more uniform quality are obtained by growing in the open field as a special crop.

The pumpkins are carefully selected, stemmed, and well washed to remove any adherent dirt. They are cut into large pieces, either by knives or roller disks, and are subjected to a general washing in a heavy squirrel cage, the principal object being to remove the seeds and loose fiber. The pumpkins are then put into large iron crates and cooked in the retort until soft, which requires about 20 minutes at 240° F.; they are next run through a cyclone, which removes the hard part of the skin and the tough fiber. The pulp proper is cooked very little if it is of a good consistency, but if light or thin it is evaporated until it is of the right body. It is filled into cans while hot, sealed at once, and processed at 250° F. for 90 minutes.

Some packers cut the pumpkins in halves and peel and core with special revolving knives. This necessitates considerable extra hand work, but is particularly advantageous when the pumpkins do not ripen uniformly. It does not have any apparent advantage over the direct-heating method if the raw material is of uniformly good quality.

Pumpkin is packed almost exclusively in No. 3 cans, which should be enamel lined, so as to prevent action on the tin, and also to aid in the retention of good color and flavor.

A good can of pumpkin when opened should be filled within one-half inch of the top; should be fairly heavy, smooth, evenly screened, free from fiber, and uniformly colored. A can lacking an inch or more of being full, containing coarse, fibrous, or thin and watery tissue, is not a first-class article and is short weight. A No. 3 can should contain at least 33.5 ounces.

Squash (*Cucurbita ovifera*) is grown and handled in the same way as pumpkin.

RHUBARB (*RHEUM RHAPONTICUM*).

Rhubarb is grown in fields, in rows 4 feet apart and hills about 2 feet apart in the rows, and cultivation is the same as for potatoes. The soil must be rich to give a luxuriant growth. The rhubarb is harvested when the leaf stems are of large size, which may be at any time from the middle of May until the middle of August.

In harvesting the best stalks are selected, the small or undesirable ones being left to take care of the plant. The pulled stalks are made into bundles; the leaf and butt are then cut off and the stems placed in crates to be hauled to the factory. The hauling is done in the same way as in the case of tomatoes.

At the factory the rhubarb is washed in large tanks of running water and at the same time inspected for any imperfections. The next step is the cutting, which is accomplished by means of a series of small saws set 1 inch apart on a shaft. The rhubarb is laid on a carrier, which feeds each stalk crosswise to the saw. The pieces ready for the can are therefore 1 inch in length and the size of the stem. The cans are filled by means of a string-bean filler, and as much is put in as can be shaken below the level of the rim. Hot water is added to fill the interspaces.

The practice in some factories differs in some particulars from that given here. First, in that the stems are stripped or peeled before being cut, and second, in that the rhubarb is heated in a preserve kettle before filling into the can. In the latter case only a very small quantity of water is used, as in the cooking sufficient juice is extracted to furnish part of the liquor in packing. This style of pack is put up in No. 3 and No. 10 cans. The former is put up only in No. 10 cans for pie purposes. The process is 13 minutes at boiling temperature. The difference in the quantity of rhubarb which will go in a No. 2 can in the raw state and blanched is as 250 grams to 400 grams. The action of rhubarb on tin and enamel is very severe, so that this product can not be made to keep indefinitely in such cans.

SUCCOTASH.

Succotash is a mixture of green corn and green beans, the Lima bean being the one generally used. Succotash has also been made from green corn and soaked beans, as in most places the corn and beans will not come to maturity at the same time. The flavor of succotash made from good corn and strictly green beans is better or more delicate than that made with dried beans; otherwise the latter is in no way inferior to that made from the green bean; but when the dried bean is used the fact should be indicated on the label. In the regular field run of Lima beans some will be further advanced than others; while the pods may all be green, in blanching some of the beans may turn white and on breaking they may appear mealy, and thus give the appearance of being soaked when the can is opened. In fancy succotash these white beans are picked out by hand. A succotash should consist of not less than 20 per cent of beans, and in the high grades there is more nearly 40 per cent beans, either graded or ungraded for size. The cut corn and blanched beans are mixed, after which they are treated in the same way as corn, being given the same sugar and salt brine, preliminary cooking, and process. The net weight in a No. 2 can should be not less than 20 ounces.

SPINACH (*SPINACIA OLERACEA*).

Spinach, which is of rather recent origin as an article of canned food, is growing rapidly in favor. The plant is grown in drill rows or sown broadcast in fields. It is harvested by cutting the entire plant close to the ground when the leaves are crisp and tender, at which time it is about 10 inches high. There is a spring crop and a fall crop, the quality being better when grown in the cool part of the season.

The leaves are stripped apart by hand, the discolored, tough, and coarse portions being removed. The next step is the washing, which must be most thorough, as the presence of any sand or grit will be detected when the spinach is eaten. The washing can be done best in a revolving cylinder after the style of a squirrel cage or blancher in which there is a perforated pipe delivering sharp sprays of water. The spinach should be fed in thin layers to insure the washing of all leaves. A test for thorough washing is to empty a can into a white dish and carefully separate the leaves, when the sand will collect at the bottom. The spinach is blanched from 3 to 5 minutes, after which it is filled into the cans by weight. During the filling it is again inspected for discolored material.

Experiments made consisted in filling No. 2½ cans with 475, 560, 640, and 700 grams (17, 20, 23, and 25 ounces). The 475 grams made the can only about two-thirds full, and on the cut-out gave 415 grams of solids and 360 grams of liquid. It was manifestly slack filled. The cans receiving 560 grams lacked 1 inch of being full, while on the cut-out the solids weighed 515 grams and the liquid 245 grams. The can had the appearance of being loosely packed. The cans receiving 640 grams were nearly level full; on the cut-out the solids weighed 580 grams and the liquid 225 grams. The appearance was that of being slightly too full, as the liquid did not quite cover and there was some browning on the outside. The cans receiving 700 grams were hard-packed; on the cut-out they gave 630 grams of solids and 170 of liquid. The can was overfilled, the product was browned on the outside, and about 25 per cent of this fill were not sterile, as the mass was so dense that the heat failed to penetrate to the center. These experiments would indicate that the proper fill is about 600 grams.

The cans are thoroughly exhausted and then processed for from 35 to 40 minutes at 235° F.

SWEET POTATO (*IPOMOEA BATATAS*).

Canning sweet potatoes is of rather recent origin, but the rapid growth of the business shows how readily a cheap food will be taken because of the cleanly manner in which it reaches the consumer and the elimination of waste in handling. The sweet potato

can not be kept in the open without shrinkage and can not be marketed like white potatoes; therefore canning is used to extend the season throughout the year. There are two varieties canned, the yellow or Jersey type, grown extensively in New Jersey, Delaware, Maryland, and Virginia, and the whiter or southern type, grown in the South. The former is preferred in most markets, owing, in part, to the better appearance, the color being a clean yellow. The southern type is sweeter but inclined to turn a rather dark, dead color and to become slightly watery.

When the potatoes are received at the factory they are graded roughly for size, those more than $1\frac{1}{4}$ inches in diameter being placed in separate boxes so that they may be given a heavier cooking without overcooking the smaller ones. They are next washed, after which they are placed in crates, the layers not being more than 6 inches deep. The crates are then run into retorts and the potatoes given a steaming at 240° F. for from 9 to 12 minutes, depending upon their size and the length of time they have been out off the ground. The object is twofold, to heat the skins so that they will come off easily and to partially cook the potato before it enters the can. A quick, high heat applied for a short time will loosen the skin much better than a low temperature applied for a longer time. The peeling is done as soon as possible after the potatoes are taken out of the retorts, and, if the work has been well done, the peel is slipped off by squeezing between the fingers and not by cutting or scraping. The fresher the potatoes are from the ground the less steaming will be required, and also the less waste. Potatoes held for several weeks or allowed to dry in the air will show double the waste of those freshly dug. Peeling is also done by the lye process, such as is used for peaches, and is successful on the freshly dug product. In addition to the spraying they are vigorously brushed by revolving brushes, but there is always need for some hand trimming. The skin is also removed by means of the abrading machines used for white potatoes; these potatoes need hand trimming, as the machine does not rub in the creases and depressions. After preparation by lye or machine the potatoes are given a preliminary cooking to soften them before being packed in the can.

The potatoes are rushed from the peelers to the filling tables so that they may be placed in the cans while still warm. Little attention is paid in filling to layering the potatoes in the cans, the object being to fill closely and then heap on a sufficient amount so that, when pressed down, the interstices will be filled. They are packed either wet or dry, the latter method being preferred. Some packers in putting up a "solid pack" add about an ounce of water to the can so that sufficient steam will be generated to prevent oxidation or darkening. The addition of any water is unnecessary, and, as soon as packers learn how to handle this product, it is probable that the practice will cease. The filling should be strictly by weight, as that is the only method of securing a uniform fill.

As soon as possible after filling, the potatoes should be given a thorough exhaust. The usual steaming for 3 minutes is insufficient, as the outside only is heated and the inside may be nearly cold. Cans examined in coming from the exhausts may show a temperature of 135° F. on the outside and top and only 70° or 80° in the center. As the heat penetrates the potato very slowly, a second heating in the retort or from 12 to 18 minutes in the exhaust box is not unreasonable. If well heated the cans are not likely to be overfilled, as the expansion will be such as to cause a part to be thrown out before capping. If the right quantity has been weighed into the can and the lid lightly crimped on before exhausting, the contents will expand to fill all interstices. The packers know that the can must be well filled to preserve the clear bright yellow color, but if the exhausting is imperfect springers or flippers are almost certain to result. The bane of a slack-filled can is darkening of color and of the overfilled can is the springer, the correction of both being proper weight and exhaust. The sealing is done in the usual way, the general practice being to process for 3 hours at boiling heat for No. 3 cans. Sterilization may also be secured by processing at 240° F. for 70 min-

utes. Some experiments were made on using temperatures above boiling for a shorter period, but as the temperature rises above 220° F. the color becomes darker.

The canning of sweet potatoes is still in an experimental state, as brokers and jobbers have demanded an appearance which has been attained for the most part by overfilling and which is prone to produce springers. These are sound and wholesome as food, but the can presents an appearance which makes it unmerchantable and, unlike products containing liquid, a part can not be withdrawn and the can resealed.

TOMATOES (*LYCOPERSICON ESCULENTUM*).

The time is easily within the memory of many persons when tomatoes were thought to be poisonous. A few persons in the Eastern States used them 70 years ago, but they did not become common until a much later period. In the West the prejudice against them persisted until less than 40 years ago. The first record of canning tomatoes is that of the work done by Harrison W. Christy in 1847 at Jamesburg, N. J. Tomatoes are now used in enormous quantities in the fresh state and head the list of all vegetables as a canned product. Thousands of bushels are also used in the manufacture of ketchups, chili sauce, and soups. The tomato is produced over a larger part of the United States than any other vegetable. It may be handled with few and simple appliances, and may therefore be canned in the home and in small factories where little capital is required, as well as in the large factories.

The development of a tomato suitable for canning purposes has been a specialty in itself. For canning the fruit should be moderately large, smooth, so that it will peel readily, ripened evenly to the stem, of a clear, red color, and having a large proportion of solid meat of good flavor. Varieties which ripen unevenly or are irregular in outline are difficult to peel and the percentage of waste is too high. Tomatoes which are yellow or purple do not have an attractive appearance on opening, and those with excessive seed cells or which are soft and watery will give the can the appearance of being slack filled or packed with water. A good pack is therefore dependent upon having a variety possessing the right qualities. The canner can not accept tomatoes of a half dozen or more varieties and get good results. He must therefore specify the variety grown or furnish the plants for his growers. The production of plants in hotbeds and cold frames to supply several hundred acres is of itself a very large task. The plants are grown in the field, the same as other crops, and a single large cannery will use the product of 1,000 acres. One ketchup manufacturer takes the entire product from more than 5,000 acres. A fair yield is 5 tons of fruit for an acre, but good cultivation and fertilization sometimes brings this up to 20 tons or more. Thirty-three bushels weigh about 1 ton.

At harvest time the fruit must be picked every day, or every other day, in order to insure collecting it when it is in its prime—just ripe, without green butts, and not overripe. It is preferable that the tomatoes be put in crates which are wide and flat rather than deep, and which will hold not more than a bushel. They can be delivered to the factory in better condition in the flat crates than in the deep ones or in baskets, as the fruit will crush if piled in too many layers. Arrival in good condition lessens the time required for peeling as well as the loss in parts cut away. The tomatoes should be delivered to the factory promptly, as deterioration begins soon upon standing.

When the tomatoes are delivered at the factory they are weighed, and inspection should be made of each load. One crate is taken out at random and dumped into a tank of water. All defective fruit can be detected at once, picked out, weighed separately, and the load docked accordingly. Rotten fruit can not be used and green fruit must be held to ripen. The separation at the factory entails extra expense in the inspection and sorting. The rotten fruit should not have been picked and

the green should have been left in the field; the only way to reduce this waste to a minimum is to employ a system of dockage.

The first step in manufacture should be proper sorting. This can be done better by a few persons than by the many peelers. Tomatoes which are green should be taken out and held in crates for one or two days, as may be necessary, but small green spots may be cut out by the peelers. The tomatoes with rot should be discarded. Tomatoes which are small, rough, misshapen, and sound, but which will not peel well, can be set aside for pulp. Such a separation will lessen the work and waste in the factory and in the end be economical. The sorting is best done upon a conveyer table, the tomatoes which are passed being fed directly into the washer.

The washing should be thorough and done without bruising or crushing the fruit. It is preferable that the fruit be dropped into a tank of water and rolled over and over gently, either by actually turning the tomato or by strongly agitating the water, and then spraying under a strong pressure as they emerge from the water. This latter operation is of greater importance than is generally supposed. As before stated, a comparatively large volume of water without force behind it is far less efficacious than a much smaller volume having force. The latter cuts off the dirt and organisms, the former only wets the skin and makes it look bright. Allowing tomatoes to dry in the sun after washing by each method will clearly demonstrate the difference. The water in the tank should be changed continuously by the addition of the water used in the spray, an overflow being provided for the tank. The majority of tomato-washing machines are inefficient.

The tomatoes are scalded, while passing slowly through a tank or steam chamber, by the continuous action of hot water or steam. The scalding is only sufficient to loosen the skin and not to heat or soften the tomato. As the tomato emerges from the scalding it is sprayed with cold water, which causes the skin to split and arrests the heating of the fruits.

The clean-scalded tomatoes are delivered to the peelers in various ways, in pails and pans by carriers or belts, or by moving table tops, or they are delivered to the tables directly upon belts. Various devices have been used to carry the tomatoes to and from the peelers and to care for the waste, the object being to secure cleanliness and careful handling of the fruit. The bucket system is an old one and is in general use at small factories. The bucket is filled with scalded tomatoes and the peeler works from one bucket into another, dropping the refuse into a third bucket or into a trough under the table. The objection to the bucket is that the fruit on the bottom is mashed more or less before being reached by the peeler, and the same is true of the peeled fruit. Wide shallow pans have an advantage over the bucket in this respect. In peeling from the special tables, the tendency is to heap the bowls too full, which produces the same disadvantages found in using the bucket. Some paint the buckets different colors to indicate whether they are to be used for scalded tomatoes, peeled tomatoes, or refuse. All buckets or pans should be washed each time they are used, no matter how many times a day that may be. All tables and conveyers should be washed each time the plant stops, and oftener when needed.

The peelers hold the tomatoes with the stem toward the palm of the hand, pull the skin back from the blossom end, and close the operation by removing the core with the point of the knife, keeping it well directed toward the center so as not to open the seed cells. This is not only the quickest way to peel the tomato, but keeps it whole. Green and undesirable spots are cut out.

The cans are filled either by hand or by machine. The sanitary or open-top cans are filled by hand, as it gives a better appearance to the finished product. In this class the cans are weighed to insure the desired fill. If filled too full, which may easily happen, "springers" or "flippers" may result, and the product be unsalable though perfectly wholesome. "Springers" or "flippers," as before explained, have the appearance of a swell, but are not due to fermentation. Solder-topped cans

seldom bulge in this way for the reason that they can not be sealed when too full, and, as a rule, they weigh from 3 to 4 ounces less than the hand-filled cans. Overfilling also necessitates a longer process, breaking up the fruit and detracting from the appearance of the product. In order to bring out the flavor some canners add one teaspoonful of a mixture of equal parts of salt and sugar, or of one part of salt to two parts of sugar, to each can. This is rarely done except upon high-grade goods and must be done by hand in order to insure uniformity.

There are several types of filling machines for solder-topped cans. A type in use for some time consists of a chamber to hold a quantity of tomatoes sufficient to fill a can, and a plunger or piston to force them in. The result is that the fruit is more or less badly broken, though just as good in quality as the handpacked. Some of the latest machines fill the cans on the principle of the collapsible tube, resulting in a much better appearing product than with the old type. During the last season machines were designed to fill the open-top can. All fill by volume rather than by weight. When the filling is done by hand the product is often designated "hand-packed" or "solid-packed," to distinguish it from that filled by machine, or filled with tomatoes and juice added to fill the interspaces. The use of water in canning tomatoes is unnecessary and constitutes an adulteration. Its only justification has been in the packing of whole-peeled or unpeeled fruit for salads, where perfect appearance rather than food value is the criterion of success. These are packed, one in a flat can, or five or six in a single layer in the large flat can, every effort being made to retain the fruit whole. The quantity packed is very small and equally good results can be obtained by using juice in place of water. The use of about 4 ounces of juice in filling the interstices in fancy selected stock materially increases the amount of whole fruit on the cut-out and adds somewhat to the appearance. The juice used for this purpose should be of the same grade as the stock and not made from trimmings.

The packing of tomatoes results in two classes of product: (1) That in which only whole stock or solid pieces are used; (2) pulp or purée. The two products are distinct and both have useful places, but one should not be substituted for the other. The term "canned tomato" applies to whole or solid fruit and not to the mixture.

The regular packed tomatoes should be well exhausted, sealed, and processed for from 35 to 55 minutes; the more solid the pack, the heavier the process required. Thirty-five minutes is not safe with most packers nor when cooling is practiced. For fancy tomatoes it is better to exhaust slowly to about 120° F., as there will be less breaking down of the fruit than if it be subjected to high heat for a shorter time. The length of time given in processing depends upon the condition of the fruit; if soft-ripe and closely packed, it will require a longer time than if firm and sound. This rule, the reverse of what is generally supposed to be true, applies throughout canning. The softer and mushier the consistency, the harder for the heat to penetrate. Some packers process in the retort at 220° to 230° F. for 25 minutes, but this has the effect of breaking the fruit. It is preferable to cool the can, as there will be a gain of from 1 to 3 ounces in solids on draining and a better color.

Somewhat too much stress is being placed upon the quantity of solid meat which will be found in a can of tomatoes after draining on a screen. A very high percentage of solid meat may mean the use of a variety which is hard and inferior, or fruit which is slightly green, in which event the flavor is deficient. The full rich flavor of the tomato is not developed until it is thoroughly ripe, so ripe that the processing will cause a part of the tissue to break down and after long shipments it may be badly broken. While it is desirable to have a large proportion of the fruit whole or in large pieces, a broken condition is not necessarily evidence of poor stock or improper methods.

The addition of juice or water to cans has a direct effect upon the cut-out, the difference being in the quantity and specific gravity of the liquid portion. The effect of adding water is shown in the following table:

Cut-out weight of solids and juice when varying quantities of water are added to tomatoes, No. 3 can.

Water added.		Gross weight.		Net weight of contents.		Weight of fruit.		Weight of liquid.		Specific gravity of liquid.
Ounces.	Grams.	Ounces.	Grams.	Ounces.	Grams.	Ounces.	Grams.	Ounces.	Grams.	
10	1,100	39.3	960	34.3	647	23.1	313	11.2		1.023
0	1,101	39.3	962	34.3	597	21.3	365	13.0		1.022
2	1,106	39.5	964	34.4	546	19.5	418	14.9		1.021
4	1,107	39.5	969	34.6	507	18.1	462	16.5		1.020
6	1,108	39.5	972	34.7	481	17.2	491	17.5		1.018
8	1,098	39.2	963	34.4	422	15.1	541	19.3		1.018
10	1,091	39.0	953	34.0	399	14.2	544	19.4		1.017
12	1,063	38.0	932	33.3	380	13.6	552	19.7		1.014
14	1,055	37.7	904	32.3	303	10.8	601	21.5		1.013
16	1,040	37.1	899	32.1	274	9.8	625	22.3		1.011

¹ Solid pack, 1911. Much better tomatoes than those which follow of the 1912 pack.

The manufacture of pulp, either as a main product or as a by-product in canning, should receive special consideration. First, there is the necessity for careful sorting, and, second, for thorough washing. Both of these operations are much more important than when tomatoes are canned, for in that case the peel, with any adherent dirt or defective material, is removed.

In the making of pulp as a by-product more or less of this objectionable material is rubbed through the sieve and can not be eliminated. For this reason sorting must be done as the first step, for it is not practicable to do it after scalding or for the peelers to do it. The washing should be of the most thorough character—first by placing the tomatoes in a hopper containing water to soak the dirt loose, and then by passing the tomatoes under pressure sprays so that all parts are exposed to the action of the water. The ordinary grasshopper or dump washer does not accomplish this end. The best washer is that used for cleansing lye-peeled peaches. It consists of a cylinder made of perforated, corrugated iron, mounted and rotated as a squirrel cage. A pipe with fish-tail nozzles directs streams of water upon the fruit at intervals of about 10 inches. The tomatoes can not slide through but must roll over, and are not handled roughly. The treatment is more vigorous than is necessary for canning operations, but is right for pulp or ketchup. With proper preliminary treatment and careful work upon the tables, trimmings need not be objectionable for pulp and are a proper source for good food material. Where tomatoes are very large and badly wrinkled the loss in solid packing reaches as high as from 50 to 60 per cent, whereas a considerable portion might be saved. The trimmings from the tables should be worked through the cyclone promptly; otherwise fermentative processes will take place.

In the manufacture of pulp as a main product, using the small, irregular, cracked, and soft-ripe fruit, the same care should be given to sorting and washing. The tomatoes may or may not be run through a scalding and go at once to the cyclone. The scalding gives a better result than the use of a crusher without scalding. The paddle beaters in the cyclone should be set back and not be made to force everything through the screen except hard fiber. By being set back the hard parts are not torn to pieces; green butts, brown mold, and corky parts are thrown over the end. On the two operations of washing and cycloning alone the difference in the amount of organisms in the product may be influenced 50 per cent or more.

A large proportion of tomato canners could advantageously sort only the finest fruit for peeling and work all other sound stock into pulp. It would eliminate from the cost of peeling much that is expensive to peel, would reduce the waste to the minimum, and lessen the number of employees required. The first operation in preparing tomatoes for soup in the kitchen is to run the contents of a can through a sieve and concentrate over the stove. This work could be done better by means of proper equipment at the factory. The contents of a No. 3 can would be reduced to that of a No. 2

can, with saving of labor, cost of cans, and freight. There is little excuse for packing seconds and pieces of tomato in juice for soup stock when a better quality can be prepared in a more concentrated form, and the water can be obtained at home at less expense.

The cooking of the pulp may be done with coils or in jacketed kettles, there being a preference for the former. It may be only slightly boiled or it may be condensed more than 50 per cent, depending upon the trade for which it is intended. Heavy pulp is canned in No. 1 and No. 2 cans for family use and light pulp in 1-gallon and 5-gallon cans for ketchup manufacturers. No standards have been made for pulp, and as a consequence there is no uniformity in the products found upon the market. The boiling pulp is run directly into cans and sealed; the process varies with the consistency and length of time taken for condensing; No. 2 cans generally receive 25 minutes at boiling temperature, and 1-gallon and 5-gallon cans, 30 minutes at 190° F. A good many packers steam the 5-gallon cans, fill them while hot, seal, and do not give a subsequent sterilization. This practice, however, is dangerous.

Until recently the tomato was packed almost exclusively in No. 3 cans, but with the introduction of the open-top cans No. 1 flat, No. 2, and No. 2½ cans are rapidly coming into use, as they furnish more nearly the amounts required in household use. There is also a large quantity of so-called gallons put up for hotel trade.

Condensed tomato or purée prepared from sound material has many advantages for some purposes over the regular canned article, and its use should be cultivated, especially for soups, etc. At the price paid for the standard grade of tomatoes a better article can be obtained as a purée or paste. Some purée is made from peel and waste from the canning. If the material is clean and sound there is no objection to its use, but too often this is not the case, as is made evident by the presence of microorganisms, broken tissue, and products of decomposition. A paste which is made from the whole tomato and from trimmings by a system of spontaneous fermentation and salting is used largely by foreigners. This article is no longer permissible in interstate trade. Another grade of paste is made by evaporating the pulp until it becomes very stiff and heavy. The straining of the juice or pulp from the seeds and hard portions can be done better and with less waste by special machinery than in the kitchen.

Tomatoes are sold under various trade grades, as extra choice, extra select, choice, select, extra standard, standard, and seconds. It is unfortunate that there are so many ways of designating the contents of a can, particularly when the prefix is meaningless. What one packer calls his "extra choice" or "extra select" may be no better than an extra standard or a standard of another packer. The real grade at present is dependent upon the packer's name, not upon what he claims. There should be but two grades—selected or first grade, and standard or field run for the second. A can of first grade tomatoes should be from selected, prime, ripe fruit, having a fleshy body, well-developed flavor, and uniform color. The can when opened should be full and most of the tomatoes whole or in large pieces, free from all peel, core, or defects. The net weight should not be less than 32 ounces in a No. 3 can.

A can of standard tomatoes should be from sound, ripe fruit, having a fair body and good flavor. The can when opened should be full, and part of the tomatoes whole or in large pieces. They should be well peeled and cored. The net contents of a No. 3 can should not weigh less than 32 ounces.

MARINE PRODUCTS.

There is a very large variety of fresh and salt water products put up in cans, and these have received the following classification by Charles H. Stevenson:¹

There are five general classes of canned marine products, viz, (1) plain boiled, steamed, or otherwise cooked; (2) preserved in oil; (3) prepared with vinegar, sauces,

¹ The Preservation of Fishery Products for Food. United States Fish Commission Bulletin for 1898, p. 512.

spices, jellies, etc.; (4) cooked with vegetables, etc.; and (5) preserved by some other process, but placed in cans for convenience in marketing.

The first class includes salmon, mackerel, herring, menhaden, cod, halibut, smelt, oysters, clams, lobsters, crabs, shrimp, green turtle, etc.; sardines almost exclusively make up the second class.

The third class includes various forms of herring prepared as "brook trout," "ocean trout," etc., mackerel, eels, sturgeon, oysters, lobsters, crabs, etc.

The fourth class includes fish chowder, clam chowder, codfish balls, green turtle stew, terrapin stew, and deviled crabs.

The fifth class is made up of smoked herring, halibut, haddock, carp, pickerel, lake trout, salmon, eels, sturgeon, etc., and brine salted mackerel, cod, and caviar.

CRABS (*CALLINECTES HASTA*).

Canned crab meat in this country was the result of experiments made by James McMenamin, of Norfolk, Va. He began at Norfolk in 1878, but moved to Hampton in 1879, and that has been the chief point of supply up to the present time. The season for catching crabs is from April to October.

The live crabs are placed in large crates, well washed, and then run into a steam box, where they are cooked for 25 minutes. After cooling they are "stripped"—that is, the shell, viscera, and smaller claws are removed. The meat is then picked out of the bodies and large claws by hand, or it may be removed by centrifugal force or by compressed air. The latter methods, which are of recent origin, are effective and save much labor. In the centrifugal method the shell and claw are cut across to expose the tissue and a quantity so prepared is placed in a centrifugal drum almost the same as that used for drying in a laundry. The drum is made to spin at a high speed and all the meat is extracted. The compressed-air method consists of an air compressor and a storage tank, with pipes leading to a nozzle. The shell is held in front of the nozzle, the air is turned on, and the meat blown out. Either method is faster, better, and cleaner than the hand picking.

The meat is filled into cans and processed. The No. 1 cans generally used are first heated for a half hour in boiling water, vented, and then processed for one hour at 240° F.

Crab meat is not so easy to keep as some other kinds, the tendency being to blacken more or less in the cans.

OYSTERS (*OSTREA VIRGINIANA*).

The oyster is a marine bivalve of the genus *Ostrea*, the species used in this country being *Ostrea virginiana*. It is found along the coast, chiefly in the shallow waters at the mouths of rivers and in bays. Chesapeake Bay has long been noted for the abundance of its oysters. They are found naturally all along the Atlantic coast as far north as Massachusetts, and at one time were abundant in Long Island Sound. Active dredging depleted the beds and now the supply is maintained only by cultivation and the restriction of dredging operations. Some oysters are canned on the coast of Virginia, the Carolinas, and Georgia, but they are no longer canned north of Maryland. The oyster occurs in the Gulf on the west coast of Florida and all along the shore to Texas. There is a large business in canning oysters in Mississippi and Louisiana. A few oysters are found on the Pacific coast, but not in sufficient quantity to warrant canning. The abundance of oysters in Chesapeake Bay made canning operations most profitable there, and the output acquired a reputation which still gives it some preference in the market. Prior to 1900 probably 95 per cent of the canned oysters were put up in Baltimore or in the immediate vicinity. The southern or Gulf oyster, however, has been proved to be equally good for canning purposes and the industry has rapidly assumed large proportions in those localities.

The oyster grows naturally on the hard reefs in from 15 to 180 feet of water, depending upon the temperature. In the Gulf they grow in shallower water. They will also grow in the bayous and flats by transplanting and furnishing shells or hard objects

to which the spawn may become attached. Formerly no regulations were deemed necessary as to the places at which oysters might be taken, but since the rivers have become polluted with city sewage, it is necessary to guard carefully against oysters from contaminated beds. The different States regulate the time when the fishing may be done, which is generally from the 1st of September until the 1st of May. The oysters for canning are usually taken from the beds between the 1st of October and the 1st of April.

Oysters were among the first products canned in this country. It is recorded that some were put up in an experimental way in New York in 1819, though they did not become a commercial proposition until the work was developed by Thomas Kensett in Baltimore in 1844. In the beginning all the oysters were shucked raw, by hand. In 1858 Louis McMurray, of Baltimore, found that by scalding the oysters in boiling water the shells would partially open and the labor of shucking could be lessened. Two years later the system of steaming them instead of scalding was developed, and no material change in method has taken place since that time. McMurray is said to have had a most excellent reputation as an oyster packer. His method was to save all the liquor and condensed steam from the steam boxes, filter it, and use it in filling the cans. He used neither salt nor water. There is probably no packer in the business at the present time following this method.

Oysters are obtained by dredging and by tonging, the former upon the reefs and in the deeper water, and the latter in the shallow bayous where planting has been done. The usual equipment consists of a schooner of about 48-foot keel, 55 feet over all, and 16-foot beam. When loaded, this will carry about 275 barrels of oysters. The crew consists of a captain and four men. A dredge is carried on each side of the boat and operated by two men. The dredge consists of a heavy iron rake about 3 feet wide, to which is attached a chain or heavy cord purse, the mouth of which is held open by an iron bar just above the rake. The dredge is lowered to the ground and dragged along by the movement of the boat. The rake loosens the oysters from the rock or ground and they are collected in the purse.

At short intervals the dredge is drawn on board by means of a windlass, the purse is emptied, and the operation repeated. The oysters are culled in some places, the small ones being returned. The catch is put in the hold if the boat is out in warm weather or is to be gone for more than a day. The trips are generally limited to from three to five days in order to insure delivery in a fresh condition at the cannery. Other varieties of smaller boats are also used, though power boats are generally barred. The Gulf-coast factories pay about 60 cents per barrel for oysters used in canning and 80 cents per barrel for those used in the fresh trade, owing to the difference in size. The barrel is rated by measure and not by weight. On the eastern coast the measurement is by the bushel.

The oysters are rated by size. If there are from 800 to 1,000 to a barrel they are known as standard, from 600 to 800 per barrel as selects, and from 450 to 600 per barrel as extra selects. The largest oysters, known as "counts" on the east coast or as "plants" on the Gulf coast, run less than 450 per barrel and are always sold raw. The larger oysters are found on certain reefs on which work has been prohibited for given periods or in certain water where planting has been done. The term "plants" when applied to eastern oysters refers to those taken from deep water, transplanted in shallow water, and cultivated until they have attained a desired size.

When the oysters are brought in, they are hoisted directly from the boat to the steaming car. These iron cars or crates are 28 inches wide, 19 inches deep, and 8 feet long. They will hold 5 barrels of $2\frac{1}{2}$ bushels each. As soon as the car is filled the oysters should be given a thorough washing with clean water to remove the dirt and mud attached to the shell before it goes to the steam box, otherwise there is contamination during the shucking. The cars are wheeled from the dock to the steam

box, which accommodates 3 cars. The steamer is a rectangular iron box, just large enough to admit the cars, and is 25 feet in length. There are a few variations from these sizes, but these are standard. The doors are closed at both ends; steam is turned on until a pressure of 10 pounds is reached, and this is maintained for 5 minutes. The doors are then opened and the oysters allowed to cool quickly in the air. It is important that the oysters be steamed well so that there will be no shrinkage in the can, but not long enough to cause them to become crummy. Both the time and the temperature at which the steaming is done seem to have been fixed by experience, as none of the superintendents seemed to know what the effect would be if a lower temperature and longer time or higher temperature and shorter time were given.

The car of steamed oysters is pushed into the shucking shed, the shuckers standing around the car and working until it is emptied. The usual number of shuckers is from five to eight, and they are generally women and children.

The steamed oyster has the shell partly opened, the meat being easily removed by means of a short, heavy-bladed knife. The oysters are deposited in pans which are hooked to the oyster car. The shucker receives 5 cents for $3\frac{1}{2}$ pounds of selects or 3 pounds of standards. The oysters are weighed as received from the shuckers, washed, and placed in cans by weight according to the grade and order. The cans are filled with a weak hot brine (2 pounds of salt to 10 gallons of water) frequently by passing the cans through a dip box. This method was used at one time in other lines of canning, but has been superseded by more sanitary methods, and should be in this case.

The cans are capped in the usual manner, either by hand or machine, and are then processed in the retort at 240° F., the No. 1 cans for 12 minutes and the No. 2 for 15 minutes. The different packers vary the time a few minutes, but practically all use the same temperature.

The oysters are cooled as soon as sterilized, and when dry are ready to pack. The oyster is easily sterilized, it is not hard on the can, and there is little loss from spoilage.

The term "cove" is applied to any canned oyster. It originally meant only the oysters obtained on the western shores of Chesapeake Bay and was distinctive of quality. Gradually any oyster became a cove oyster, and now the term refers to canned oysters irrespective of where they are obtained.

SALMON.

Salmon canning on the Pacific coast is one of the large canning industries, and is of so much importance that Government aid is extended in maintaining fish hatcheries in order to keep up the supply. The first salmon canning was done on the Sacramento River in 1864, later on the Columbia River in 1866, in British Columbia in 1874, and in Alaska in 1882. The value of the salmon pack on the Pacific coast is more than \$10,000,000 annually.

There are four species of salmon which have large commercial importance—*Oncorhynchus tshawytscha*, the chinook, quinnat, red spring, or King Alaska; *O. nerka*, the sockeye, blueback, or redfish; *O. kisutch*, coho, silver, or silver sides; and *O. gorbuscha*, humpbacks or pink Alaska. Preference is given to the bright pink color by the consumer, but for real quality the paler coho excels some of the others, the flesh being less dry and containing more oil and a better flavor.

The salmon are caught in the rivers as soon as practicable after they leave the sea on the way to the spawning grounds. They are caught by nets, seines, traps, and fish wheels. The catching of the fish is done on an elaborate scale, an idea of which may be gained from a brief description of a trap. This consists of a steel-wire netting, starting at the shore and carried out into the stream at an upward angle for a distance of about 2,500 feet. This netting is supported by piles placed about 15 feet apart. At the outer end is a large square compartment known as the pot. This is usually about 40 by 40 feet and in water as deep as 65 feet. This pot contains a dip net equal to its area. Just previous to reaching the pot the trap is made to zigzag or assume a heart shape, so that the fish in trying to pass up the stream will be directed into the pot.

Adjoining the pot is a spiller, which is similar in construction, but of smaller size, having a tunnel or opening connecting the two. The fish pass from the pot to the spiller and are taken out by the dip net or brailer, which is 12 by 12 feet and is cast and drawn on board the boat by power, literally lifting out hundreds of fish at a time. They are hurried to the factory as rapidly as possible, where they are unloaded upon the dock by means of elevators or pews.

It is the general practice to permit the fish to remain out of water in bins for 24 hours before canning, as a certain amount of shrinkage takes place; otherwise there may be excessive blowing of the juice on venting. The fish are washed free from slime or gurry before they go to the butchering room.

The dressing of the fish, or butchering as it is called, is done speedily, mostly by machinery. The head and tail are sawed off on a band saw, where formerly they were cut off with a cleaver. The fish is then fed into the "chink" tail first and back down. By the revolution of this wheel, the fins are removed by special knives, the body is split open, the viscera torn out, and the interior wall scrubbed by revolving brushes. The dressed fish is delivered into a tank of water, and the offal delivered with the gurry. The iron chink does a better job than is done by hand, and is the most important machine in the canning of salmon. After the fish has been dropped into the tank of cold water, it is scrubbed thoroughly with brushes until it is clean.

The dressed fish is placed upon a special slitted elevator, which feeds it transversely into a series of revolving disks, which cut it into lengths corresponding to the height of the can. There are a variety of lengths used, but there are three which are standard; the No. 1 tall, No. 1 flat, and the half pound. Seven knives are used in the gang for cutting for tall cans, 13 knives for flat, and 17 knives for half-pound cans.

The grading of the fish is done on the basis of solid and less desirable body cuts. The filling of the choice parts is done by hand, and each can weighed. The short weights are supplemented by bits, but overweight is not reduced. Much of the filling, especially of the less expensive cuts, is done by machinery. The cans used must all be open top, and this is later either soldered or the joint made with a double seamer.

The solder capping of the cans is different from that practiced in other packing. First a piece of tin with the corners bent up is placed on the fish, then the can is set in a machine which wipes the upper edge, after which the end is put in place, and the can passed through another machine which crimps the end to the sides. This end contains a small hole or tip. The can then rolls, head downward, into a V-shaped groove which contains flux, and continues its rolling in another section of the groove containing solder, and it is here that the final sealing is done. The heating of the contents, due to the hot solder, causes some steam to be generated, and it is for the purpose of allowing this to escape that the piece of tin is placed within and under the vent. When the can leaves the soldering trough it is turned over and the vent closed or tipped. With sanitary cans no tin nor vent is needed, the cap being attached and sealed by machinery.

The cans are then placed in trays, the standard size being 35 inches square and 3 inches deep. Each tray will hold 160 tall or 86 flat standard No. 1 cans, the cans being on end in a single tier. The test for leaks is to set the tray in boiling water for a few seconds and watch for bubbles. Eight trays make a basket, and this constitutes a charge for the retort.

The process consists of heating at 220° F. for 30 minutes, then taking out the fish, venting, and retipping, and giving a subsequent heating for 1 hour and 15 minutes at 250° F. When open-top cans are used, the filled cans are run through an exhaust box very slowly so that they are thoroughly heated before the cover is attached. Venting becomes unnecessary, but the time of cooking remains unchanged—that is, the single heating is equal to both periods under the old method. The hot cans are immersed in lye to remove grease and oil and are then cooled in water. The net weight of the 1-pound tall or flat can should average 16 ounces.

SARDINES (SARDINIA).

The sardines caught on the Pacific coast are much larger than those taken in the East and are handled in a different manner. They are caught in nets at night, and on being brought to the factory in the morning are put into bins and kept wet with running water for some hours. They are then dressed, scaled, heads and viscera removed, and again thoroughly washed in two or more changes of water. They are next dipped in strong salt brine for a few minutes, rinsed, and placed in wire trays to dry. In order to expedite the drying the trays are carried through a mechanical drier so that all surface water will be removed. The crates are then dragged through a vat of boiling oil, the length of time being that necessary to cook the fish thoroughly, usually about five minutes. They are left in the crates until cool, which is usually until the following day, placed in the cans by hand, oil or sauce added to fill the interspaces, carefully exhausted, and processed at 240° F. for 1 hour and 15 minutes.

SHRIMP (PANAEOUS BRASILIENSIS).

The shrimp is a crustacean and belongs in the same general class as crabs, crayfish, and lobsters. There are a number of varieties found in this country, but the one used for canning is the Gulf shrimp, *Panaeus brasiliensis*. The shrimp found in the fresh waters and west coast are used fresh, but are too small to be used in canning. The Gulf shrimp resembles a large crayfish and is from 5 to 7 inches long. They inhabit the deep waters and come to the shore twice each year. They are active swimmers and are provided with very long antennæ. The abdomen is the only part of the shrimp that is used, the head and thorax being thrown away.

The first attempt to can shrimp was made by Mr. G. W. Dunbar, of New Orleans, in 1867. His efforts did not meet with success until 1875, at which time he devised the bag lining for the cans. In 1880 a factory was started at Biloxi, Miss., and from that time to the present the majority of all the shrimp canned has been put up in these two cities. It is only within the last 10 years that the canning of shrimp has assumed considerable importance, but it is still limited to about a dozen places in Louisiana and Mississippi. A cannery was started in Texas, but failed to secure a regular supply, and the oyster canneries in Florida could not secure enough to make it profitable to prepare to receive them. The early supply of shrimp was obtained from Barataria Bayou, or Lake, which gave the distinctive name, Barataria shrimp. The name is often improperly used now. The shrimp sent to England are called prawns.

Shrimp are caught in February, March, and April, and in September, October, and early November. The run is uncertain, and a catch depends upon the state of the weather; the quantity taken is very irregular. The shrimp are caught only in shallow water along the shore. Previous to 1911 all catches had to be made in less than 6 feet. Newer apparatus has been invented, making it possible to take them in water 10 feet in depth. The shrimp are located by coursing over the ground in a small sailboat, or a skiff, and trying with a cast net. This is a circular net from 6 to 8 feet in diameter, with leads every few inches around the edge and a cord attached for drawing it together. A man stands at the bow of the boat and makes trial throws until a school is located. When the shrimp are found the large seine is anchored on the shore at one end and the boat rowed out and around as large an area as the seine will cover. As soon as the second end is brought to the shore the men bring the two ends together and begin to draw in the seine. If the weights hang close upon the ground the chances for a catch are good, but if the seine should rise the shrimp will find a way out very quickly. The handling of the seine requires wading in water from 2 to 4½ feet in depth. The seine is drawn in such a manner as to cause the shrimp to go into the purse in their attempt to escape.

As soon as the catch is made safe the boat is brought alongside and the shrimp dipped out with scoop nets. They are stowed promptly in the hold of the vessel and well iced if the weather is warm or the trip is to continue for more than a day. The seines used in shrimp fishing are from 150 to 225 fathoms in length (900 to 1,350 feet)

and from 140 to 150 meshes wide. (A mesh is three-quarters of an inch, giving a width of 105 to 112 inches.) The net apparatus for handling the seine consists of a stake with special pulleys near the bottom, so that the seine may be drawn from below without a tendency to raise it off the ground.

The boat equipment for catching shrimp is essentially the same as for handling oysters, so that they are used interchangeably. The seine takes the place of the dredges and windlass, and the crew is usually made up of five or six men. Each boat will carry about 140 barrels of iced shrimp.

Shrimp are weighed instead of measured, a barrel being 200 pounds. The pay for catching is \$3.50 per barrel in the fall and \$4 in the spring. The fall run is the more certain catch and requires less ice, which makes the difference in the schedule of prices.

When the shrimp are brought to the dock they are stored in ice until ready to use. The ice makes the peeling easier and is necessary to prevent spoilage. The removal of the head and shell is known as "peeling" the shrimp, and this is done for all canned shrimp. The head and thorax break from the heavy tail with ease and a slight squeeze will separate the fleshy portion from the shell. This work is done rapidly; the pay for peeling is about 1 cent per pound. The peeled shrimp are thoroughly washed in two or more changes of water and are then ready for blanching. The blanching consists in boiling the shrimp in salt water, which is done by suspending them in a wire basket in the boiling brine. The time of the blanch is usually about four minutes for the wet pack and five minutes for the dry pack. The salt in the brine is in the proportion of about 1 pound per gallon of water. Up to the time the shrimp go into the blanch they are white or slightly gray in color; the boiling in the brine causes them to become bright pink or red.

The shrimp are turned out upon trays having wire netting. As soon as cool they are filled into cans by hand, each can being weighed. The shrimp are all packed in either No. 1 or No. 1½ cans, the former having 4½ ounces and the latter 9 ounces. There is no attempt at grading.

Shrimp are put up in what are known as dry and wet packs. In the dry pack no liquor is added, while in the wet pack brine is used. The process for dry shrimp is 1 hour at 240° F. or 4 hours at 212° F. for No. 1 cans, and 75 minutes at 240° F. and 4 hours at 212° F. for No. 1½ cans. The process for wet shrimp is 11 minutes for No. 1 and 12 minutes at 240° F. for No. 1½ cans.

The fill of 4½ and 9 ounces in the No. 1 and No. 1½ cans has the appearance of being light weight or slack filled. Experience has shown, however, that close filling causes matting of the shrimp and an unsightly appearance. The wet-packed shrimp are preferred by those who are familiar with the fresh article. They have better texture, odor, and taste than the dry packed. A barrel of good shrimp will pack 190 No. 1 cans or 100 cans of No. 1½.

Formerly shrimp were put up in bulk with a preservative. These were headless (only the head and thorax removed, the shell left on), and since that method of preservation is no longer approved, very few shrimp are obtained upon the market other than canned. Some pickled headless shrimp are put up in 1 to 5 gallon cans for hotels. These are boiled in strong brine for several minutes and put up in a saturated salt solution. They keep, but are very salty, and as it takes a long time to freshen them they are not available for immediate use.

Shrimp are difficult to keep. Put up in the ordinary tin can they will blacken in a short time and will attack the tin, making minute holes. Success in canning shrimp was dependent upon lining the can. This was first done by Mr. G. W. Dunbar, of New Orleans, in 1875. The method consisted in inserting a sack in the can and filling it with the shrimp to prevent their coming in direct contact with the tin. Later a thin veneering of wood, corn husks, parchment paper, asphaltum, and enamels were used. Parchment paper is used by all packers, with possibly one exception, at this time; in this case wood veneer is used.

SPECIALTIES AND SOUPS.

BEANS, BAKED.

Pork and beans, beans and tomato sauce, and baked beans are the ways which the labels read on the product which a few years ago was known only as "baked beans." The beans used for this purpose are the small white pea or navy bean. They are chiefly grown in New York, Michigan, and Wisconsin and are a regular field crop, sowed, cultivated and harvested when ripe and used only in the fully ripe dried state. The quantity used in this way is enormous.

The beans should be of good quality, small, white, machine cleaned, and hand picked for defects. The first step in preparation is soaking, and this is done in tanks or barrels and lasts from 12 to 24 hours, depending upon the method of handling. The water is changed in the tank about once in 6 hours, or, on the fancy article, about once in 4 hours.

From this point on the preparation varies greatly in different factories. For the very cheap trade the beans are boiled in a squirrel cage or pea blancher for a few minutes before placing them in the can; others boil them very slowly in an iron-jacketed kettle from 30 minutes to 3 hours before canning. Some boil them just long enough to slip the skin, the length of time depending wholly upon the grade of the bean.

Before the cans are filled, a piece of pork is placed in the can, then the beans, and finally the sauce. The sauce varies greatly, though tomato sauce is the most popular at present. This is made from a good heavy pulp, salt, sugar, and spices, the proportions being varied to suit the fancy of the packer. Plain sauce is made with water, salt, sugar, molasses, and spice. It is important that just the proper quantity of sauce be added, for in the processing some moisture will be taken up by the beans, and if too little sauce or moisture is added they will be dry and hard, while if an excess be added they will be sloppy.

In these methods there is no real baking, the beans having been soaked and boiled. They are subsequently heated in the can at a baking temperature, but no moisture can escape, and baking generally implies that the material is subjected to dry heat, usually in an oven. The real characteristic is the change in and breaking up of the tissues with loss of weight, due to the escape of moisture. Formerly baking was done under hot ashes or coals, in clay or brick ovens; now it is done in stoves and special ovens, and the latter may be heated by steam. The same results may be accomplished in superheated steam as in hot air. The difference between baking and roasting is not always clear, but between baking and boiling there is a distinction. The term "baked" beans, therefore, implies that they have been exposed to a dry heat. This is accomplished by heating the soaked beans for a short time, until they soften but do not break open or become mushy. They are then placed in large pans in thin layers and allowed to bake in ovens until they become dry and mealy and develop the characteristic brown color. The beans, when poured upon the filling table, will readily separate from one another. Another method is to place the beans in large trays in the retort and subject them to dry steam until dry and mealy. The result is almost the same as in the oven—a loss of about 8 per cent in weight taking place and giving the same dry baked bean. These are filled in the can and sauced, as has already been described.

The processing of beans will depend altogether upon the method of preparation, usually from 1 hour to 2½ hours for a No. 2 can, at a temperature of from 245° to 250° F.

There is probably no staple canned which presents more variety in quality and flavor than the bean. The best is a high-grade product, the beans used are expensive, and the dressing, if made of tomato, is good pulp, the same care being given in its preparation as is used in preparing any other. Not so much can be said for some of the very cheap brands; the beans used are inferior, the pulp used is from trimming stock, and the object is to get as much water in the can as possible. The net weight of beans in a No. 2 can should be not less than 19 ounces.

HOMINY.

Canned hominy is used in every mining and logging camp in the country. It is primarily the diet for the hard worker, but is also used with milk to take the place of a breakfast food in thousands of homes. It was first packed in 1895 by Mr. I. V. Smith, of Delphi, Ind., and almost immediately others followed.

Hominy is made from selected white corn. The shelled grain is screened to take out all small, defective, or split grains, and any chaff or foreign substance. It is then washed and run into the lyeing machine. Here the corn is treated with a hot solution of lye, during which time it is constantly cooked and agitated until the tough hull loosens. The strength of the lye and the length of time required for the cooking vary at different factories; the time of cooking varies from 20 to 45 minutes. After the lye has accomplished its work the grain is run through a huller, which is in reality a short conical "cyclone," which removes the hull and tips.

The grain is next washed in a squirrel cage, pea blancher, or hominy washer. The different canners use very different methods at this point. Some soak the corn overnight in order to have the kernels swell to the maximum before canning; others soak and cook for only a short time, an hour or two; while some fill the cans at once and depend upon the swelling in the process to give the desired result. The soaking has the effect of getting rid of traces of lye, makes a more tender kernel, and a clearer liquor. The cans are so filled that when the process is completed the grains fill the can nearly full and should be covered by only one-fourth inch of liquor. The liquor should be fairly clear and few black tips present.

SAUERKRAUT.

Sauerkraut is made by the natural fermentation of cabbage in casks. The cabbage heads are stripped of all outside or green leaves, leaving only the white sound head. It is then cut into thin slices in a specially constructed machine. The long, fine-cut cabbage is evenly spread and well packed in casks. To each layer salt is added at the rate of about 2 pounds per 100 pounds of cabbage. The salt is used as flavoring and to modify in some degree the fermentation. If too much salt is used, a pinkish color results; if too little, the fermented product may become more or less slimy. The temperature of the weather at the time of putting up the cabbage also influences the fermentation. If the weather is very warm, the fermentation is too rapid, the product has a very white but more or less slimy appearance, and the cabbage is tough rather than of a natural crispness. If the temperature is very low, fermentation will be arrested. The best temperature is probably between 60° and 70° F., and the process requires about 4 weeks. Fermentation begins as soon as the cabbage is placed in the cask, but there is only a slight rise of temperature as compared with most fermentation processes. A heavy foam rises to the top, which must be skimmed off every day, and when this ceases to form the brine goes down and the process is complete. Use can be made of the kraut at once, though it seems to be better after standing. The kraut will keep in the casks for a long time, provided there is no leakage, and the spoilage is usually limited to a few inches on the top.

Kraut is easily canned, which is the only clean way of dispensing it in groceries in small quantities. The canning should be done where the kraut is made. The shipping of kraut in barrels to distant points to be canned has nothing to commend it and much to condemn it. The repacking in barrels means labor and loss of material, and in too many cases the loss of natural brine, after which spoilage takes place easily. The canning should be done while it is in the freshest possible state at the point of production. Kraut is easily kept. The cans should be filled full, weighed, and sufficient hot water added to fill the can; then exhausted, capped, and processed at boiling temperature for 25 minutes.

Experiments were made upon the fill of kraut in No. 2½ cans with the following results: Kraut 690 grams, can packed full, gave as a finished product a gross weight of 930 grams, solids 680 grams, liquor 110 grams, the brine lacking more than 1 inch of covering; kraut 590 grams, the can full but not so tight as in the former, finished, the can weighed 920 grams, the solids 600, liquor 180 grams. The brine did not cover by nearly three-fourths of an inch and the can was evidently overfilled. The third lot contained kraut 490 grams, and finished the gross weight was 915 grams, kraut 510 grams, and brine 265 grams. The brine did not quite cover, but the condition was very good.

A properly filled No. 3 can should not contain less than 22 ounces of kraut as determined by emptying upon a sieve of one-eighth inch mesh and allowing to drain for two minutes.

SOUPS.

Soups of almost every description may be obtained in cans. There is no standard, but each one is made according to the formula of the particular packer. Some soups are concentrated, while others are ready for use. They are practically all packed under Government inspection, both of the plant and the materials used. No meat products can enter interstate trade without being inspected, and since nearly all soups contain either meat or stock made from meat, they must comply with all the requirements governing meat inspection.

Soups are classed as meat or vegetable, though there are but few of the latter that are not made from some kind of meat stock. The usual procedure in making soup is to select the meat stock, which is usually beef, though veal or mutton may be added. The meat used by some of the best factories is of the very highest quality, not merely any meat which has passed inspection. This is cut into pieces, the size depending upon whether it is to be used in the soup or only for the stock, and is placed in large steel kettles. These are heated by steam and covered tightly, so that the stock may be cooked slowly without evaporating. The cooking is continued below the boiling point for several hours, depending upon the kind of meat used and the care given to the making of the soup. The slow cooking has the effect of bringing out the extractives, giving a better flavor and a richer product. The liquor is skimmed at regular intervals, and if the stock is for a clear soup or a bouillon it is clarified with eggs and filtered. If for a soup containing the meat, this last operation may be omitted.

The vegetables used in making soups are carrots, turnips, parsnips, peas, beans, onions, leeks, celery, okra, tomatoes, etc. As far as possible, these should be used in their fresh state, but as it is not possible to have them all fresh at the same time the canned article must be substituted. The vegetables used are prepared separately, washed, peeled, cut into pieces, cubes or special forms, blanched, and in some cases given a separate cooking to get the proper tenderness. These are mixed in the proportions desired, placed in the cans by weight, and the stock added afterwards. The process will depend upon the body, whether thick or thin, and the quantity of meat used.

The making of soups is peculiarly a chef's work; it is not possible to give a formula for so many pounds of meat and vegetables, set a definite time for cooking each, and get a first-class product. The characteristic flavoring depends upon the blending and the condiments used, which is a matter of training and judgment. For meat soups the best packers follow the practice of holding the cans in stock for some weeks in order that they may improve on standing. A good soup requires much work in its proper preparation, much more than is given in the canning of fruits or vegetables. Many soups are made according to formula, and while of good material, are not distinctive.

A list of soups includes the following: Beef, bouillon, celery, oxtail, mock turtle, veal, chicken, chicken gumbo, consommé, green turtle, clam broth, clam chowder, mutton broth, tomato, tomato-okra, vegetable, pea, asparagus, mulligatawny, vermicelli, and Julienne.

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HOMEMADE LIME-SULPHUR CONCENTRATE.

By E. W. Scott,

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During the past few years much attention has been given by investigators to the home preparation of lime-sulphur concentrate and also to an inquiry into the chemical reactions involved, as affecting the conditions under which the work should be done. These investigations have had for their purpose the encouragement of orchardists in the preparation of concentrates for their own use, or for the use of the neighborhood. The success of these efforts is shown by the fact that many fruit growers now prepare their own lime-sulphur concentrates, thus effecting a material saving over the cost of the commercial article.

Orchardists, as a rule, are not able consistently to obtain a product of uniform density, even though the same formula be employed and the work be accomplished as nearly as possible in an identical manner for the different batches. This defect, however, is really of little importance, since it is easy to test the density of the concentrate and make dilutions in conformity with the purpose for which it is to be used.

During the past few years the Bureau of Entomology has given attention to the making of lime-sulphur concentrates in connection with work in deciduous-fruit insect investigations. No particular chemical study was planned in connection with these cooking tests, as it was merely desired to know the degree of density and percentage of the "sludge" which would result by the employment of different formulas. The cooking tests for the most part were made at lime-sulphur plants operated by orchardists, or by individuals who supplied the concentrate to orchardists in the immediate territory.

EXPERIMENTS AT BERRYVILLE, VA.

Six experiments were conducted at a small plant at Berryville, Va. This plant consisted of a 12-horsepower boiler and two 150-gallon cooking vessels. The cooking was done by steam which was

NOTE.—Describes experiments in making lime-sulphur concentrates and gives the most satisfactory formulas. Of interest to all practicing spraying in insecticide work.

ejected through perforated coils in the bottom of the tanks. There was no mechanical agitator, the mixture being agitated by hand by the use of a long wooden paddle. The mixture was allowed to cook 50 minutes, when, after taking samples for testing purposes, the remainder was drained into a storage tank. The results of these tests are given in Table I.

TABLE I.—*Results of cooking different lots of lime and sulphur in preparation of lime-sulphur wash, Berryville, Va., 1912.*

Experiment No.	Formula.			Percentage in volume of sludge.	Degrees Baumé.
	Lime.	Sulphur.	Water.		
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Gallons.</i>		
1	50	100	50	39.0	28.5
2	50	100	50	50.0	30.0
3	50	100	50	35.0	29.5
4	50	100	50	41.5	30.5
5	45	100	50	41.0	29.0
6	55	100	50	44.0	28.0

The 50-100-50 formula was used in the first four of these experiments. The Baumé test of the cooked wash varied from 28.5° to 30.5°, and the percentage in volume of sludge, after standing 24 hours, varied from 35 to 50. The preparation of the wash in experiments 1 and 3 was as nearly the same as was possible, the lime being added first and the sulphur immediately afterwards. In experiment 2 the sulphur was added first.

In experiment 4 the mixture was not stirred after the steam was turned on, the steam being depended upon for agitation. Otherwise the treatment was the same as in experiment 1.

In experiments 5 and 6 the quantity of lime was decreased and increased 5 pounds, respectively, from the amount previously used. This was done to determine, if possible, whether more or less of this particular brand of lime should be used. In every other respect the treatment was the same as in experiment 1. The only points considered in this experiment were the Baumé test and the percentage in volume of sludge.

EXPERIMENTS AT WINCHESTER, VA.

A lime-sulphur cooking plant located at Winchester, Va., also was visited. This plant, which has a capacity of 500 gallons per day, consists of a 150-gallon rectangular sheet-iron tank embedded in a brick furnace in which wood is burned to furnish the heat. This plant supplies a number of the surrounding fruit growers with lime-sulphur solution. As soon as the cooking has been completed, the solution is piped directly through a 20-mesh strainer into 50-gallon barrels and is delivered to the growers without being filtered. The strainer, of course, takes out only the coarser particles; therefore it is necessary for the grower thoroughly to shake the barrel each time

any of the solution is taken out in order to get an even distribution of the sludge. The following data were obtained, which show the variation in density of the different batches. Four batches in which the 50-100-50 formula was used tested 25°, 26°, 28°, and 29° Baumé, respectively. Seven batches in which the 55-110-50 formula was used tested 28°, 29°, 29°, 30°, 30°, 30°, and 31° Baumé, respectively. It will be noted that there was considerable variation in degrees Baumé for the different batches, although each was cooked as nearly as possible in the same way.

Similar variations in density were observed at a steam-cooking plant at Chewsville, Md.

EXPERIMENTS AT HAGERSTOWN, MD.

A new lime-sulphur cooking plant at Hagerstown, Md., was visited. The cooking vessels, two in number, consisted of the hulls of two large boilers standing on end. Each held about 1,500 gallons. The cooking is done by steam. A few experiments were conducted at this plant to determine, if possible, what formula should be used under these conditions of manufacture to obtain a highly concentrated solution. The results of these trials are given in Table II.

TABLE II.—*Results of cooking different lots of lime and sulphur in preparation of lime-sulphur wash, Hagerstown, Md., 1912.*

Experiment No.	Formula.			Percentage in volume of sludge (estimate).	Degrees Baumé.
	Lime.	Sulphur.	Water.		
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Gallons.</i>		
1	800	1,600	800	35.0	25.5
2	800	1,600	800	35.0	26.0
3	750	1,500	285 gallons sludge, 715 gallons water.....	40.0	23.0
4	200	400	Added to above 1,000 gallons of 23° Baumé material	45.0	27.0
5	1,000	2,000	280 gallons sludge, 620 gallons water	45.0	32.5

In Experiments 1 and 2 800 gallons of solution were cooked at a time. The 50-100-50 formula was used in each of the two experiments with a result of 25.5° and 26° Baumé test solution respectively. In each case there was about 35 per cent in volume of sludge. The solution in Experiment 1 was allowed to remain in the vessel 24 hours, then the clear solution was drawn off and 285 gallons of sludge remained in the tank. In order to see what effect this sludge would have on the solution by cooking it over with the next batch (Experiment 3), 715 gallons of water were added to it, making 1,000 gallons in all; 750 pounds of lime and 1,500 pounds of sulphur were added to this and the mixture was cooked for one hour. After allowing the solution to settle 24 hours the clear liquid tested 23° Baumé and there was 40 per cent in volume of sludge. An attempt was made to raise the test of this solution (Experiment 4) by adding

to it 200 pounds of lime and 400 pounds of sulphur. After cooking this for an hour and allowing it to settle there was 45 per cent in volume of sludge and the clear solution tested 27° Baumé. In an attempt to make a high-test solution by using a reduced quantity of water mixed with sludge Experiment 5 was conducted. To the 280 gallons of sludge remaining in the cooking vessel from Experiment 2 there were added 620 gallons of water, making a total of 900 gallons. To this was added 1,000 pounds of lime and 2,000 pounds of sulphur. This was cooked for one hour, and after allowing it to settle for 24 hours there was 45 per cent in volume of sludge, and the clear solution tested 32.5° Baumé. It will be seen that a high-test solution was obtained by reducing the quantity of water, but the percentage of sludge was also considerably increased.

EXPERIMENTS AT VIENNA, VA.

A few lime-sulphur cooking experiments were conducted at Vienna, Va., in the spring of 1911. A large iron pot placed over a wood fire was used as a cooking vessel. In four of these experiments the 50-100-50 formula was used. The time of cooking was from 45 minutes to one hour. The results, which show variation in Baumé test and a high percentage in volume of sludge, are given in Table III.

TABLE III.—*Results of cooking different lots of lime and sulphur in preparation of lime-sulphur wash, Vienna, Va., 1911.*

Experiment No.	Formula.			Percentage in volume of sludge.	Degrees Baumé.
	Lime.	Sulphur.	Water.		
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Gallons.</i>		
8	8	16	8	40.0	30.6
9	40	80	40	33.0	28.8
10	40	80	40	40.0	28.7
11	40	80	40	50.0	27.0

EXPERIMENTS AT BENTON HARBOR, MICH.

Some experiments were conducted at Benton Harbor, Mich., in the fall of 1912 for the purpose of making high-test solutions. The cooking plant consists of a 12-horsepower boiler from which steam is conducted into two 50-gallon barrels. There are no coils in the bottom of the barrels, the steam simply being emitted through the open end of a straight pipe extending to within a few inches of the bottom of the barrel.

Small batches amounting to 25 gallons of the finished product were cooked at a time. About 20 gallons of water were put into the barrel, then the steam was turned on and the water brought to boiling. The lime was then put in and after it had begun to slake the sulphur was

added. The mixture was stirred thoroughly throughout the time of cooking, which lasted 1 hour. It was allowed to settle about 12 hours, and then the clear solution was siphoned off. The sludge was put into a cider press and the clear solution pressed out, using 10-ounce canvas cloth for filter. A good grade of stone lime was used in experiments 1 to 5. Hydrated lime was tried in experiments 6 and 7. Commercial ground sulphur was used in all the experiments. The results are given in Table IV.

TABLE IV.—*Results of cooking different lots of lime and sulphur in preparation of lime-sulphur wash, Benton Harbor, Mich., 1912.*

Experiment No.	Formula.				Degrees Baumé.
	Lime.	Sulphur.	Water.	Sediment.	
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Gallons.</i>	<i>Pounds.</i>	
1	25	50	25	32	27.0
2	25	50	25	36	27.0
3	40	80	25	80	34.0
4	40	80	25	90	35.5
5	40	80	25	85	32.5
6	¹ 60	80	25	110	30.0
7	¹ 60	80	25	100	31.5

¹ Hydrated.

In Experiments 1 and 2 the 50-100-50 formula was used, with a result of 27° Baumé test solution in each case and 32 pounds of sludge in Experiment 1 and 36 pounds in Experiment 2. In Experiments 3, 4, and 5 the same proportion of lime and sulphur as above stated was used, but the amount of water was reduced, the formula being 40 pounds of lime and 80 pounds of sulphur and water to make 25 gallons of concentrate. The Baumé tests of these three batches varied from 32.5° to 35.5°, and the amount of sludge varied from 80 to 90 pounds. The sludge, after it had been run through the cider press, was in the form of a thick paste, so the number of pounds given does not nearly represent the number of pounds of dry sediment.

The formula used in the last two experiments was 60 pounds of hydrated lime and 80 pounds of sulphur with water to make 25 gallons of concentrate. Where the hydrated lime was used the solution did not test so high and there was considerably more sludge.

DIRECTIONS FOR PREPARATION OF LIME-SULPHUR CONCENTRATE.

The 50-100-50 formula has been generally recommended for the preparation of home-boiled concentrated lime-sulphur solution. The method of preparation is to boil together for 50 minutes to 1 hour 50 pounds of lime, 100 pounds of sulphur, and water to make 50 gallons of the concentrated solution. A good grade of fresh stone lime containing not less than 90 per cent of calcium oxid is necessary for the best results. Hydrated lime is sometimes used,

but it is necessary to use a good grade and at least 20 per cent more of this form of lime, as it contains a high percentage of moisture.

Place enough water in the cooking vessel to finish with 50 gallons of the solution. Bring the water to the boiling point, start the agitator, if the plant is equipped with one, then put in the lime and immediately add the sulphur. The mixture should be stirred vigorously either mechanically or by hand until the lime is slaked. Agitation should be continued throughout the time of cooking, which should not exceed one hour. If the solution is to be barreled without filtering, it should be drawn off immediately and allowed to run through a 30-mesh strainer into the barrels. The agitation should continue until all the solution is drawn off, so that there will be an equal distribution of the sludge in the different barrels.

PREPARATION OF HIGHLY CONCENTRATED LIME-SULPHUR SOLUTION.

From the experiments above reported, it is evident that a highly concentrated lime-sulphur solution may be made by using the lime and sulphur at the ratio of 1 to 2 as is usually recommended, but with reduced quantities of water. The formula used in the commercial lime-sulphur manufacturing plants visited and also in the foregoing experiments is as follows:

Fresh stone-lime	pounds..	80
Commercial ground sulphur.....	do....	160
Water to make the finished product.....	gallons..	50

While there is about 50 per cent in volume of sludge after allowing this solution to settle for 24 hours, there is only about 5 to 10 per cent in volume of insoluble materials. These consist of sulphites, free lime, free sulphur, magnesium compounds, etc., varying with the kind of lime used and other conditions. Solutions prepared by this formula should test on an average 33° to 34° Baumé.

RELATIVE COST.

Commercial ground sulphur can be bought in car lots for about \$1.50 per hundred pounds, and lime at about 60 cents per barrel. At these prices the highly concentrated solution can be made at the following cost per barrel:

80 pounds lime at 60 cents per barrel.....	\$0.20
160 pounds sulphur at \$1.50 per hundredweight.....	2.40
Labor and fuel, estimated.....	.70
Total cost per barrel of 50 gallons.....	3.30

This does not include interest and wear on outfit, and cost of containers for storing. At the foregoing prices of ingredients the high-test concentrate would cost about 98 cents more per barrel than the lower-test concentrate made by the 50-100-50 formula.

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 198

Contribution from the Office of Experiment Stations
A. C. TRUE, Director

Washington, D. C.

PROFESSIONAL PAPER

April 21, 1915

REPORT UPON THE CYPRESS CREEK
DRAINAGE DISTRICT, DESHA AND
CHICOT COUNTIES, ARKANSAS

By

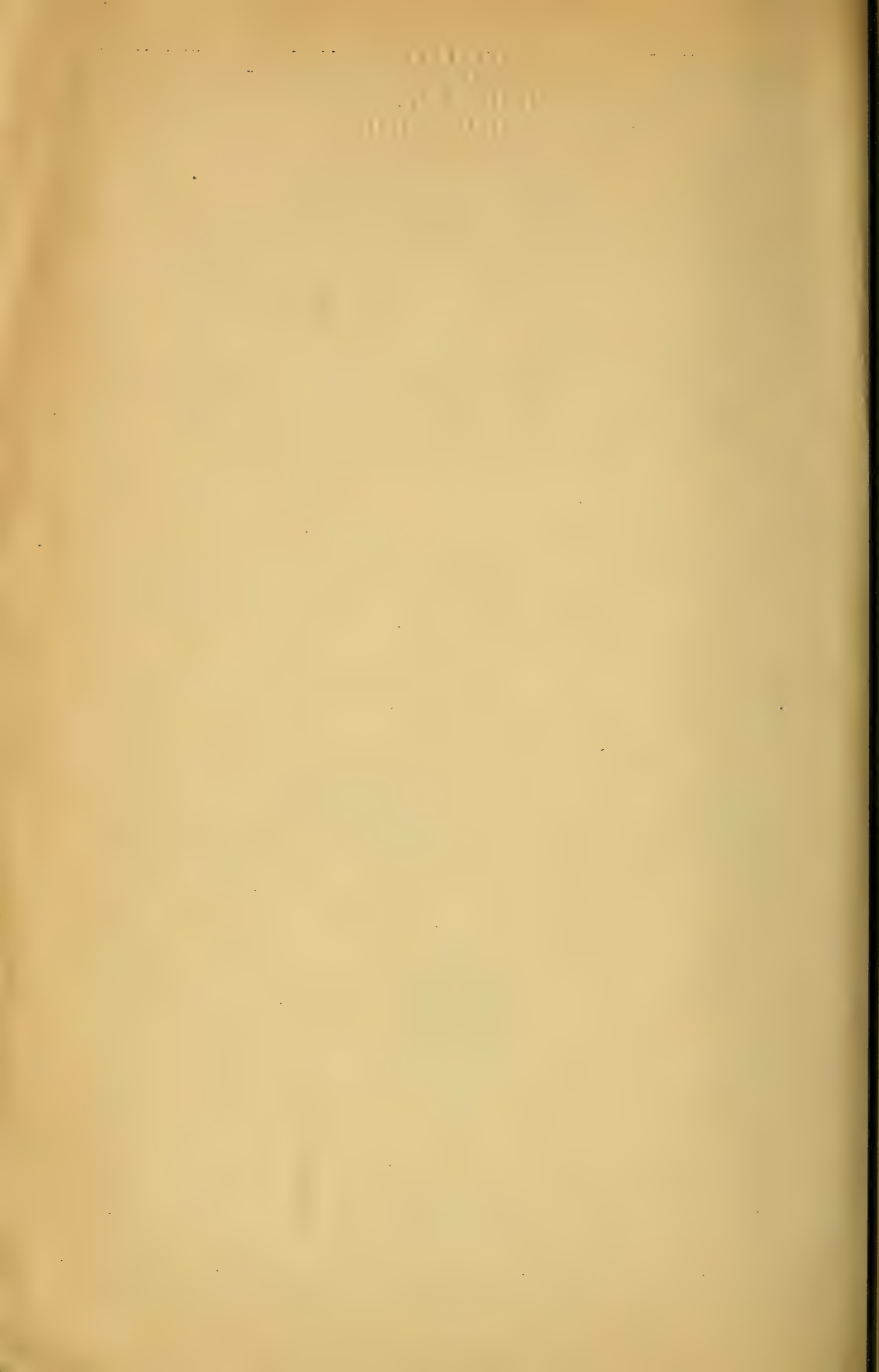
S. H. McCrory, O. G. Baxter, D. L. Yarnell, L. A. Jones
and W. J. Schlick, Drainage Engineers

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REPORT UPON THE CYPRESS CREEK DRAINAGE DISTRICT, DESHA AND CHICOT COUNTIES, ARKANSAS.

By S. H. McCrory, O. G. Baxter, D. L. Yarnell, L. A. Jones, and W. J. Schlick,
Drainage Engineers.

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INTRODUCTION.

The levees that line the lower Mississippi River ordinarily protect the adjacent alluvial lands from overflow, but this protection is usually only the first step in reclaiming those lands from excessive wetness. The occasional tributaries require that openings be left through the levees or that the streams be diverted long distances from their natural courses. Levees are built along such large tributaries as the Arkansas River, but the junctions of the smaller streams with the Mississippi often permit backwater from the main river to overflow large areas at times of extreme floods.

The southward slope of the general land surface is exceedingly flat, the greatest slope being away from the river to the foot of the hills. The low area is cut with many winding bayous, large and small, each with banks elevated above the adjacent surface approximately in proportion to the depth of the channel. These high banks, so characteristic of alluvial lands, pond the water upon the area and

NOTE.—This bulletin will be of interest to landowners, engineers, and others interested in the reclamation of swamp and overflowed lands along the Mississippi River below the mouth of the Missouri River.

prevent drainage. The conditions in the Cypress Creek drainage district of Desha and Chicot Counties, Arkansas, are typical.

It has long been apparent that an interior drainage system is needed to supplement the sixty-odd miles of levee built to protect this district from the floods of the Mississippi and Arkansas Rivers. In 1906, John T. Stewart, drainage engineer of the Office of Experiment Stations of the United States Department of Agriculture, made a survey for the relief of the wet land in the neighborhood of Arkansas City, that project being known as Desha County Drainage District No. 1. The improvements constructed in that district were, however, of only local benefit. The first active step in the direction of a comprehensive drainage system for the county was taken in 1907, when engineers of the Mississippi River Commission made a survey which had among its objects the location of a feasible line for the diversion of Cypress Creek. The report on that survey stated that the project was entirely feasible, but recommended that further surveys be made before construction was undertaken, in order that other routes might be compared with the one laid out.

No further action was taken until early in 1911, when further assistance was requested from Drainage Investigations, Office of Experiment Stations, United States Department of Agriculture. An agreement was ultimately reached whereby Drainage Investigations undertook to make the survey, one-half the cost to be paid by the Cypress Creek drainage district, which had in the meantime been created by the Arkansas Legislature.¹ The survey was begun in September, 1911, and completed in March of the following year.

GENERAL DESCRIPTION.

LOCATION AND AREA.

The Cypress Creek drainage district borders the Mississippi River in southeastern Arkansas (see fig. 1), including about 65 per cent of the total area of Desha County and extending 2 miles into Chicot County, which is in the southeast corner of the State. Memphis is about 110 miles northeast and Little Rock about 85 miles northwest of the center of Desha County. Arkansas City, the county seat, and McGehee are the most important towns in the district; Pine Bluff, on the Arkansas River about midway between Desha County and Little Rock, and Helena, 60 miles north on the Mississippi River, are cities of local prominence.

As defined by the legislative act, the district is roughly triangular in shape, with an apex to the south. Its greatest width east and west is about 23 miles, near the north end, and its extreme length north and south is approximately 36 miles. The total area is 466 square miles.

¹ Thirty-eighth General Assembly of Arkansas, Acts 110 and 445.

TOPOGRAPHY.

The land may be classified as Mississippi bottom land, nearly the whole district being below the higher flood stages of the river or of the bayous when their waters are held back by the river floods. The highest land lies in the northwest corner, the extreme elevation being in the neighborhood of 170 feet above sea level. In the southern part of the district elevations as low as 128 are found. In the northern part the fall to the south is quite well defined, as is also the fall to the east in the western part. The land bordering the Mississippi River, however, slopes away from that stream. Below Cypress



FIG. 1.—Map of Arkansas, showing location of Cypress Creek drainage district.

Creek, in the central part of the district, the slope of the land to the south is much less. Stretches of land are found here with a practically uniform elevation for several miles, broken only by the elevated banks of intervening bayous that act as barriers to the flow of drainage water southward. These conditions result in vast accumulations of water that in even ordinarily wet seasons cover these flats, making the country impassable for long periods.

The general trend of the streams for a considerable distance after they enter the district from the west is to the southeast. As they

encounter the belt of elevated land bordering the river, however, they are diverted directly south, their waters eventually reaching Bayou Macon. An exception to this condition is Cypress Creek. As may be seen by figure 1, this stream maintains an outlet directly into the river at about the center of the eastern boundary of the district. It is owing to this fact that a continuous levee can not be constructed along the front of the district under present conditions to exclude the damaging river floods.

AGRICULTURAL CONDITIONS.

The cultivated areas are mostly confined to the high lands along the bayous, and at present comprise probably not more than 10 per cent of the district; all of these will be benefited by the proposed ditches, which will afford outlets for underdrainage. The top soil generally is the ordinary Mississippi alluvium, modified more or less by decayed vegetation. Cotton forms the main crop, though some rice is grown in the north part of the district along the Arkansas River. While by far the larger part of the district is wooded, the area has been fairly well cut over and the larger timber removed. Some logging is still done, but the cutting of railroad ties and stave bolts forms a considerable part of the timber industry. Fairly good roads are maintained along the high-banked bayous, but travel over the roads of the low lands of the interior is rendered uncertain by overflow. Land values depend largely upon accessibility and degree of drainage.

PRESENT DRAINAGE CONDITIONS.

MISSISSIPPI RIVER FLOODS.

Primarily, the reclamation of the area covered by the Cypress Creek drainage district is dependent upon the exclusion of the flood water of the bordering rivers. Before the levees were constructed along the Mississippi and Arkansas Rivers, the larger part of the area now included within the boundaries of the district had been subject to intermittent overflow from these streams. The period during which some measure of protection has been had from levees extends back a great many years. During all this time the levees have from time to time been increased in cross section, as higher flood stages demanded and as funds permitted, until now, so far as they have been constructed at all, the levees are expected to afford protection against any flood that may be looked for in the light of past experience. The flood of 1912, during which the river rose at Arkansas City to a stage of 2.5 feet higher than any previous record, required the temporary raising of the levee, but did not cause any crevasses along the Desha County front. Apparently the only serious defect in the levee system is the gap at the mouth of Cypress Creek. By reference to figure 2 it will be seen that in the southwest corner of T. 10 S., R.

1 W., there is a gap of about 2 miles between the southern end of the Arkansas River levee and the northern end of the Mississippi River levee. It is, of course, impracticable to close this opening without first diverting Cypress Creek. The existence of this gap partially nullifies the benefits from these levees so far as this district and a considerable area to the south are concerned. Figure 2 (in pocket at end of bulletin) shows the area in Desha County that was submerged by the Mississippi River flood of 1912, due to the inflow of water through this opening. This amounts to about 202,000 acres, or approximately two-thirds of the total area of the district. No crevasses occurred in the levees bounding the district during this flood, and but for the existence of the levee gap there probably would have been no damage from the river itself.

DRAINAGE OUTLETS.

The small degree of interior drainage now existing is secured through the numerous bayous and creeks which meander through the district (see figs. 3 and 4, in pocket at end of bulletin). The drainage from that portion north of Amos Bayou is discharged into the Mississippi River through Cypress Creek, being collected by a number of tortuous and ill-defined tributaries distributed generally over the area. The drainage tributary to Amos Bayou, as well as that from the entire area of the district south of this bayou, is discharged into Macon Lake, whose northern end is located about 3 miles south of the Desha-Chicot County line.

The bayous are of the usual type encountered in the Delta section, being tortuous, frequently ill defined, and of irregular width. They often widen out into lakelike bodies of practically dead water and again contract into narrow channels. They are usually encumbered with drift and debris of all sorts, and particularly in their wider portions often contain growths of standing timber and various forms of water-loving vegetation. As these bayous approach the Mississippi River they usually undergo a marked contraction in cross section. This peculiarity is probably due to the backing up of river water in these bayous before the levees were constructed, the resulting obstruction to the current causing the deposition of suspended matter brought down from above. The land immediately adjoining the bayous is usually higher than that a short distance back from the streams. This condition, characteristic of Mississippi Delta bayous, as of the river itself, is especially marked along Amos and Macon Bayous, whose banks are frequently as much as 6 to 10 feet above the general elevation of the surrounding area.

The existing outlets are not sufficient to care for the run-off tributary to them. A moderate winter rain, even when the Mississippi is at normal stage, causes the flooding of large areas. The high banks of the bayous prevent a quick return of this water to the channels, and thus the lowlands remain covered with water for long

periods after the streams themselves have returned to a normal stage. A similar condition occurs when the land is flooded by back-water coming through the levee gap from the river. The land being lower than the banks of the streams, a large area is left covered with water, which disappears very slowly.

THE SURVEY.

Base level lines were run along the railroads and cross-level lines were run on all east and west section lines. All bayous and water courses were meandered and channel sections were taken where needed; in many cases levels were carried with the meanders. A base level line was carried through Lincoln County on the main line of the St. Louis, Iron Mountain & Southern Railway, and some cross-level lines were run in this county as aids in the determination of the topography of the watershed. A reconnaissance of Lincoln County was also made. The levels were tied to precise level bench marks at Arkansas City, Trippe Junction, Walnut Lake, and Varner.¹

Bench marks² were set approximately one-half mile apart on the level lines. Usually these were root bench marks, the trunk of the tree being blazed and the number of the bench mark inscribed. These were set as near as practicable to section and quarter section corners.

Soil borings were taken on the main ditch lines, and these borings, showing the character of soil encountered, are indicated on the profiles (fig. 6, in pocket at end of bulletin).

Gauging stations were established at various points over the district, and daily records kept of the gauge readings. The highest water-surface elevations observed are shown in figure 2. Current meter measurements were begun in March, 1912, during the heavy rains, but it was impossible to continue them, owing to the backwater from the Mississippi River, which flowed through the gap in the levee. The boundary of the flooded area (fig. 2), due to inflow through this gap, was obtained by personal observations and was checked by the gauge heights as furnished by the gauge readers.

THE DRAINAGE PROBLEM.

The water from which the district must be protected comes from two sources; first, direct precipitation upon the watershed in which the district lies, and second, overflow from the Mississippi River,

¹ The descriptions and elevations of these bench marks were obtained from U. S. Geological Survey Professional Paper No. 46 (1906). That publication states that the elevations of these bench marks are referred to mean Gulf datum, but since the conclusion of the survey it has been found that these elevations had been corrected by a small constant. The results obtained from ties made to the Mississippi River Commission bench marks show that 7.35 feet should be subtracted from Memphis datum elevations in order to reduce them to the datum used in this survey.

² A list of the bench marks set, with their elevations, locations, and descriptions, is on file with Drainage Investigations, United States Department of Agriculture.

whose backwater enters the district through the gap in the levees at the mouth of Cypress Creek, damaging not only the district itself, but a large area in Chicot County, Arkansas, and northern Louisiana, since such water, once behind the Mississippi River levee, must flow south to the Red River. The drainage problem, then, is not only to provide the necessary outlets and laterals to care for the run-off from the 658 square miles tributary to the district, but to so design and locate these outlets that the drainage water now entering the Mississippi River through the levee gap will be diverted, thus making it possible to close this gap. With the construction of these outlets and the closing of the levee gap the reclamation of the district will be assured.

RUN-OFF.

No phase of the preliminary study of a drainage project has a more vital bearing upon the success of the undertaking than the determination of the rate of run-off for which provision must be made. Obviously, precipitation is the most important element to be considered in the study of run-off, although certain other factors have more or less effect upon the rate of run-off. These are the size, shape, and topography of the watershed; the character of soil and vegetation; the rate of evaporation; the climate and seasons; and the water storage capacity of the soil, stream channels, and other natural reservoirs.

RUN-OFF INVESTIGATIONS MADE.

RAINFALL.

Southeast Arkansas is characterized by high humidity and heavy rainfall. The rainfall records of the United States Weather Bureau for Arkansas City and Pine Bluff have been carefully examined, the former station being the only one in the Cypress Creek drainage district. The records for Pine Bluff, however, may be taken as indicating rainfall conditions on the upper portion of the Cypress Creek watershed.

The average annual rainfall for Arkansas City, including the year 1912, is 45.23 inches, and for Pine Bluff, 49.63 inches. The records for Arkansas City for the years 1897 to 1911, inclusive (not including the years 1907 and 1908, for which records are incomplete), show the greatest annual rainfall to have been 70 inches, in 1911, and the minimum to have been 26.83 inches, in 1901. At Pine Bluff the maximum annual rainfall for the same period was 82.89 inches, in 1905, and the minimum 37.21 inches, in 1901. The greatest monthly rainfall recorded at Arkansas City was 15.42 inches in December, 1911, and at Pine Bluff, 15.71 inches in May, 1905.

Some of the heaviest storm periods at Arkansas City during the 16 years preceding 1913 were as follows: December 7-16, 1911, 9.7 inches;

August 13-16, 1911, 7.9 inches; February 9-15, 1908, 9.7 inches; and July 27-August 2, 1902, 9.2 inches. The heaviest 48-hour rainfalls were: August 13-14, 1911, 7.1 inches; February 13-14, 1908, 6.8 inches; and July 30-31, 1902, 7.8 inches. The greatest 24-hour rainfall recorded at Arkansas City occurred on April 4, 1911, when 5.6 inches fell. Other heavy 24-hour storms were 5.5 inches on July 17, 1906; 5.5 inches on August 13, 1911; and 5.1 inches on December 27, 1904. From January, 1897, to December, 1912, there are recorded 13 days when 3 inches or more fell in 24 hours, and 63 days when 2 inches or more fell in a like period. The most intense rainfall on record at Arkansas City occurred on July 17, 1906, when 4.8 inches fell in 2 hours.

Among the heaviest storm periods at Pine Bluff were: November 16-21, 1906, 10.3 inches; May 4-6, 1905, 9.4 inches; and January 1-3, 1897, 9 inches. The heaviest 48-hour rainfalls were: November 16-17, 1906, 6.6 inches; May 4-5, 1905, 8.8 inches; and July 31-August 1, 1902, 6.9 inches. The heaviest 24-hour rainfalls on record at Pine Bluff are: 5.65 inches on January 21, 1906; 6.8 inches on May 4, 1905, and 5.58 inches on January 3, 1897. Other unusually heavy 24-hour storms recorded are 4.7 inches on November 19, 1907, and 4.7 inches on July 31, 1902. During the 16 years from 1897 to 1912 there were 32 days when 3 inches or more fell in 24 hours, and 84 days when a rainfall of 2 inches or more was recorded.

STREAM GAUGING AND OTHER INVESTIGATIONS.

During the spring of 1911 run-off investigations were made on Boggy Bayou, the outlet for Desha County district No. 1. The area of this district is 165 square miles above the point where the discharge measurements were made. On April 4, 1911, occurred the heaviest 24-hour precipitation on record. This caused a measured discharge of 1,815 second-feet, or a run-off of 11 second-feet per square mile from the district. In March and April, 1912, very high stages occurred in Boggy Bayou. During the latter part of March and April, the Mississippi River rose very rapidly, and probably about March 27-29 the water began to flow from Cypress Creek and Wells Bayou to Boggy Bayou through Johnson Brake, Newman Slough, and Amos Bayou. The water begins to take this course when the Mississippi River backwater reaches an elevation of approximately 149 in Cypress Creek. It is probable that under present conditions the maximum discharge from Boggy Bayou due to precipitation alone seldom, if ever, exceeds that of April 4, 1911.

Stream measurements were made on Cypress Creek at the Memphis, Helena & Louisiana Railroad bridge south of Watson in March, 1912, until the backwater from the Mississippi River became too high. These measurements show that just before the river water

began to back up the creek on March 28 the discharge was 2,730 second-feet from a drainage area of 390 square miles, or 7 second-feet per square mile. Considering the heavy rains that followed, it is safe to say that a much greater discharge would have been obtained if a measurement could have been taken on April 4.

A current-meter measurement was made of Black Pond Slough at the railroad bridge west of Halley on the evening of April 4, 1911. This measurement gave a discharge of 449 second-feet from a drainage area of 23.5 square miles, or the rate of run-off was 19.1 cubic feet per second per square mile.

In planning the improvements of the Bogue Phalia, in Bolivar County, Miss., the 24-hour run-off was one-half inch from a drainage area of 350 square miles. The results so far observed seem to justify the use of this coefficient. The conditions in the Bolivar County district are very similar to those in the Cypress Creek district.

Other run-off data for the Mississippi Valley have been examined, including those obtained in Coahoma County, Miss., by C. W. Okey, and much that have been compiled by the Tallahatchie drainage district, Mississippi.

DETERMINATION OF RUN-OFF COEFFICIENTS.

Experience has shown that draining and clearing timbered land results in an increased rate of run-off, and so far as the district in question is concerned, there is ample reason to believe that such will be the case. The water that under present conditions can reach the main outlets only by circuitous routes will, after the drainage system is installed, have direct access to the drainage outlets through the numerous submains and laterals penetrating the interior. Such storage capacity as now exists will be greatly reduced. The substitution of deep, well-aligned ditches for the existing tortuous, debris-filled natural channels will facilitate the movement of the water from the entire drained area; in other words, will cause a quicker and more intense run-off than obtains under present conditions. In view of the effects that draining the land will have, it would be unsafe to base the selection of the run-off coefficients entirely upon the results of any gaugings made under present conditions, although these are useful in serving as checks upon such conclusions as may be reached.

In deciding upon the run-off coefficients to be used for the Cypress Creek drainage district the following method was pursued: A trial coefficient was selected for a small area, one for a medium area, and one for a large area, and an algebraic expression was then sought whose curve would approximately fit these plotted coefficients. The run-offs for intermediate areas were then calculated and plotted and the curve thus obtained was compared with all the data derived

from the gaugings. The formula was changed and the investigations continued until a satisfactory curve was obtained.

After an examination of the results of the gaugings heretofore described, taking into consideration the probable effect that the reclamation of the district will have on the rate of run-off, and after a study of some of the larger drainage districts in the immediate vicinity of the Cypress Creek drainage district, the following tentative assumptions were made as to run-off:

From 5 square miles, 1 inch in 24 hours (26.88 second-feet per square mile); from 25 square miles, $\frac{3}{4}$ inch in 24 hours (20.20 second-feet per square mile); from 400 square miles, $\frac{1}{2}$ inch in 24 hours (13.44 second-feet per square mile).

It was found that Fanning's formula could be converted into an expression whose curve fulfilled these assumptions. The conversion of this formula is as follows:

Fanning's formula is: $Q = 200 M^{\frac{2}{3}}$

Where Q = run-off from whole area, in second-feet,
and M = area of watershed, in square miles.

Substituting K for 200, and RM for Q (where R = the run-off in second-feet per square mile), we have:

$$RM = KM^{\frac{2}{3}} \text{ or } R = \frac{KM^{\frac{2}{3}}}{M} = \frac{K}{\sqrt[3]{M}} \quad (1)$$

$$\text{whence } K = R\sqrt[3]{M}$$

Substituting the three assumed values of R and M , we have:

For $R = 26.88$, $K = 35$

For $R = 20.2$, $K = 34.5$

For $R = 13.44$, $K = 36.4$

Replacing the constant, K , by 35 in formula (1), we have:

$$R = \frac{35}{\sqrt[3]{M}}$$

This expression, which has been used for calculating run-off in this project, is represented by the curve in figure 5. It was found to agree fairly closely with what gaugings have been made, giving in most cases values somewhat greater than the gaugings showed. As has been pointed out, however, overflow and backwater affected some of the gaugings and tended to give discharges less than the actual ones. Allowance has also been made for increased run-off to be expected after drainage.

DRAINAGE PLANS CONSIDERED.

Before the final plan, as hereafter stated, was decided upon, other possible methods were carefully worked out and compared.

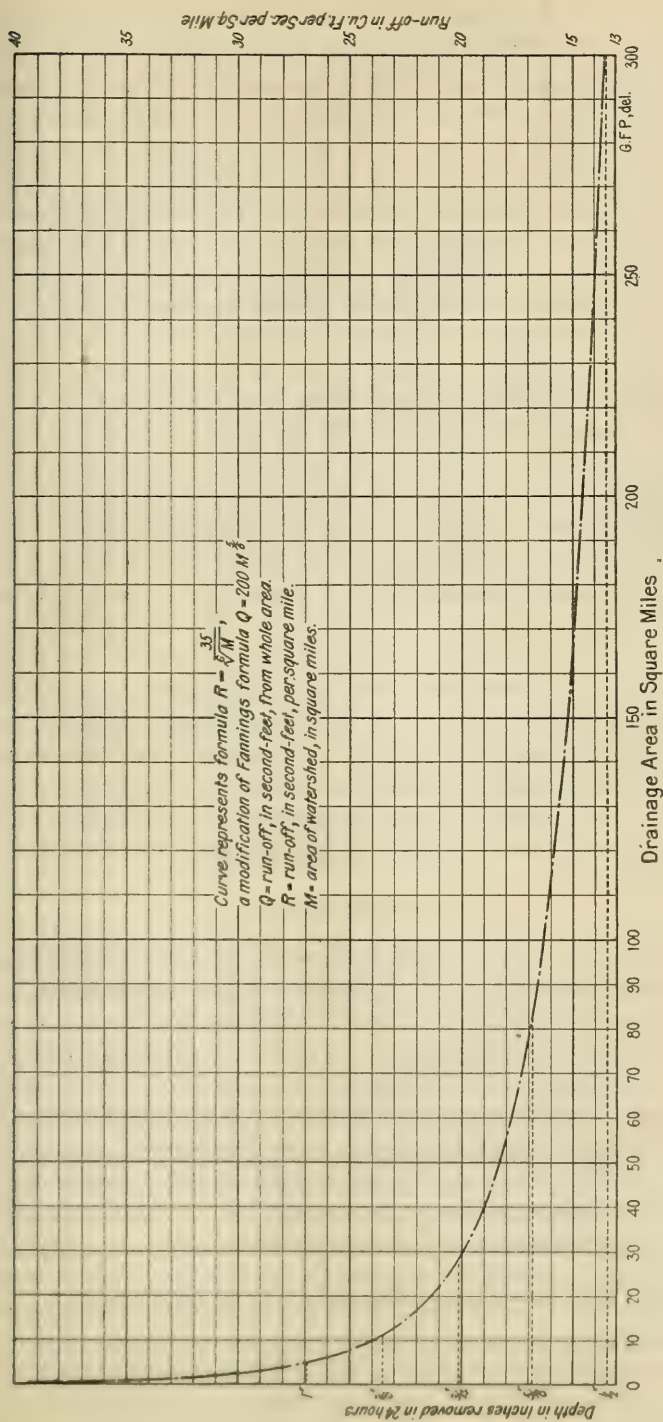


FIG. 5.—Curve showing run-off to be provided for by proposed drainage ditches.

MISSISSIPPI RIVER COMMISSION PLAN.

The plan of the Mississippi River Commission, made in 1907, provides merely for the diversion of Cypress Creek in order that the gap in the levee may be closed, and makes no provision for the further drainage of Desha County. The suggested course of the diversion is through Boggy Bayou, Boggy Lake, Clay Bayou, and Clay Bayou Wash into Macon Lake in Chicot County. The plan provides for 2,300 second-feet of flow at Boggy Cut-off and 3,150 second-feet above Macon Lake, requiring a channel of 60 to 80 feet in bottom width, with side slopes $1\frac{1}{2}$ horizontal to 1 vertical, flowing 11 to $11\frac{1}{2}$ feet deep.

The area drained by Cypress Creek is approximately 413 square miles, and that by Clay Bayou about 582 square miles. Using the drainage coefficients determined from figure 5, the capacity of the diversion channel should be 5,300 second-feet at Boggy Cut-off and 7,050 second-feet at Macon Lake. In order to obtain a proper fall in the ditch and to give drainage to the upper district, it would be necessary to hold the high-water surface in this diversion channel 3 to 4 feet below ground level. Since 15 to 16 feet is about the deepest economical excavation, the depth of flow should be about 12 feet. The required channel would then be 140 to 185 feet, 15 to 16 feet deep, with 1 to 1 side slopes. There are two reasons for rejecting this plan in favor of the ditch plan recommended: First, the cross section of the necessary channel is too great for the most economical construction; second, it will not serve effectively as the main drainage outlet for the district, principally because of the high banks along the larger tributaries. It has no advantage over the plan herein recommended.

FLOODWAY PLAN.

A system involving a combination of ditches and floodway was worked out in detail. This plan provides for carrying the drainage from Wells Bayou, Cypress Creek, and Oak Log Bayou through a floodway from Amos Bayou, in sec. 30, T. 10 S., R. 2 W., to Bayou Macon near McArthur. From here the channel of Bayou Macon was to be cleared as in the recommended plan. The drainage from a small area at the head of the Coon Bayou watershed would, under this plan, be diverted into the head of Bayou Macon. The remainder of the Coon Bayou drainage was to be carried under the floodway to the ditches in the eastern part of the district.

The floodway would be a canal 90 to 200 feet in bottom width, excavated 5.5 to 23.7 feet deep, with levees on each side 4.5 to 13 feet high, except at the banks of Amos Bayou and Bayou Macon, where no levees would be required. The total earthwork for this floodway was computed to be 2,186,000 cubic yards, which is estimated would

cost 15 cents per yard owing to the unusual depth of cut and to the added work of placing the spoil in good levees. The total cost of the floodway and the auxiliary ditch system necessary was estimated approximately equal to the cost of the ditch plan presented in the following pages.

The floodway plan is not recommended because the unusual difficulties of construction have rendered the estimate of cost less certain than that for the ditch plan, because the attitude of the landowners in general is opposed to a channel between levees, but principally because of the greater danger if maintenance work is neglected. Very few drainage ditches are regularly inspected and kept in even fair condition, usually being entirely neglected until serious overflows occur. An ordinary ditch is injured little when its capacity is overtaxed, and aids in removing the water quickly both during and after the overflow period. If this floodway were constructed, however, and by reason of improper maintenance or unprecedented flood flow it should be overtaxed, not only would great expense be necessary to repair the damage to the levees, but the embankments remaining in position would tend to prevent the water from returning into the channel.

DITCH PLAN.

This plan includes the clearing of Bayou Macon and Boggy Bayou, but otherwise generally disregards the natural watercourses for main drainage channels. It is presented as being the plan that will give the best drainage results with the minimum difficulties of construction and cost of maintenance, and is discussed in detail below.

THE RECOMMENDED PLAN.

DRAINAGE DISTRICT BOUNDARIES.

Cypress Creek drainage district, according to the boundaries defined in act 110 of the Thirty-eighth General Assembly of Arkansas, contains 298,450 acres, or 466 square miles. The total drainage area tributary to the district is 658 square miles, of which 188 square miles are in Lincoln and Jefferson Counties (see fig. 4) and 13 square miles in Drew County. The drainage district should include only such land as would be benefited by the improvements. On this basis the following described boundaries are proposed, as a result of the survey:

The district should include all of Desha County lying south and west of the Arkansas and Mississippi River levees, as now constructed and surveyed, except that part lying west of the following described line: Beginning 2,000 feet north of the southwest corner of sec. 7, T. 9 S., R. 4 W., and running east to the left bank of Choctaw Bayou; thence following the left bank of Choctaw Bayou to Walnut Lake; thence following the left bank of Walnut Lake to the north and south

quarter line of the NW. $\frac{1}{4}$ sec. 9, T. 10 S., R. 4 W.; thence in a general southerly direction, following the west watershed boundary of the district as shown on the map (fig. 3). The district should also include the following land in Chicot County: All that portion of T. 13 S., R. 1 W., lying west of the Mississippi River levee; all that portion of secs. 6 and 7, T. 14 S., R. 1 W., lying west of the Mississippi River levee; all of secs. 1, 2, 3, 4, 10, 11, and 12, and those portions of secs. 5, 8, and 9, T. 14 S., R. 2 W., lying east of the west watershed boundary of the district. That part of Drew County, containing 8,474 acres, lying east of the district watershed boundary should also be included in the drainage district. With these boundaries, the district would contain 294,784 acres, or 460.6 square miles.

THE DITCH SYSTEM.

In planning this system it was of course necessary to keep the sizes of all outlets within the limits of practical construction. For this reason certain diversions were necessary (see fig. 3).

Wells Bayou, now emptying into Cypress Creek, is diverted in sec. 9, T. 10 S., R. 4 W., by ditch No. 13, flowing into Bayou Macon in sec. 3, T. 12 S., R. 3 W. It is not feasible to divert the water from Wells Bayou into Bayou Bartholomew on account of the high stages that occur in the latter stream, which probably would be considerably increased if Wells Bayou were discharged into it. There is an impression among the local residents that at times Bayou Bartholomew discharges considerable water into Wells Bayou through Cross Bayou in T. 9 S., R. 6 W. An examination made at this point on April 3, 1912, on which date occurred the highest stage ever recorded in Bayou Bartholomew, showed only a very small amount of water entering Wells Bayou from this source.

The diversion of Cypress Creek is accomplished as follows: First, all that portion above the south line of sec. 13, T. 9 S., R. 4 W., is diverted at this point by ditch No. 19, flowing directly to Bayou Macon in sec. 18, T. 11 S., R. 3 W. The latter stream is to be improved from this point to Macon Lake. Second, ditch No. 43 crosses Cypress Creek in sec. 1, T. 10 S., R. 3 W., which will take the drainage from Oak Log Bayou, now tributary to Cypress Creek, directly south to Macon Lake. Third, by a combination of channel improvement and ditch No. 81 the drainage tributary to the lower end of Cypress Creek is carried to Macon Lake through Boggy Bayou, Boggy Lake, Clay Bayou, and Clay Bayou Wash.

The diversion of the greater part of Cypress Creek into Bayou Macon, as noted above, will so raise the level of this stream in the vicinity of the present mouth of Little Bayou Macon that other provision will have to be made for the latter outlet. The drainage tributary to Little Bayou Macon is therefore carried south by ditch No. 18

into Lost Chain Creek and thence into Bayou Macon in sec. 32, T. 13 S., R. 2 W.

Although natural channels have been utilized wherever possible, it was frequently found advisable to locate the ditches entirely independent of existing streams, on account of the high banks, poor alignment, and cost of clearing of the latter.

Laterals are provided in sufficient number and of such depth as to afford good drainage to the areas lying back from the mains when the necessary field ditches are constructed.

DETAILS OF DITCHES.

All of the proposed work is shown in figure 3. Profiles of ditches Nos. 13, 18, 19, 43, 66, 67, 76, and 81 are shown in figure 6 (in pocket at end of bulletin). Tables of hydraulic and construction data for each ditch are on file with Drainage Investigations, United States Department of Agriculture.

Kutter's formula has been used in all cases in computing the capacities of the ditches. A roughness coefficient of 0.025 has been used for all artificial channels and of 0.035 for existing channels that are to be cleared. In ditch No. 19, from station 949 to station 976, where the channel of Coon Bayou is to be cleared and grubbed, a coefficient of 0.030 was used. Where practicable, the proposed high-water lines in the channels are placed 1 to 2 feet below the surface of the ground. The grades are made as uniform as practicable, and at points where the grade is decreased, thereby necessitating larger ditch sections, the depth of flow is increased rather than the bottom width, in order to avoid great changes in velocity.

The minimum ditch planned has a bottom width of 14 feet, side slopes $\frac{1}{2}$ to 1, and depth of flow 6 feet. This is the smallest that can be constructed economically by a floating dredge in timbered lands. The width of berm is independent of the width of the ditch, but varies with the depth of excavation. For cuts of 10 feet or less a berm of 10 feet is planned; for cuts of 10 to 15 feet a berm of 12 feet; and for cuts deeper than 15 feet a berm of 15 feet is proposed.

In existing channels where clearing is the only improvement needed all timber and underbrush should be cut and all debris removed. No stumps should project more than 18 inches above the ground. A short section of ditch No. 19, in Coon Bayou, will need to be cleared and grubbed in order that it may have the required capacity; in this section all stumps should be removed or cut level with the ground in addition to the ordinary clearing.

The widths required as right of way for the ditches were computed by taking three and one-half times the top width of the ditch plus the width of both berms. The cost of right of way was estimated at \$20 per acre. No allowance was made for this cost where the ditches follow present channels.

All improvements were planned from the data collected by the preliminary survey, as the ditches have not been located in the field. The location survey may show that some slight changes would be advisable, but such changes will not materially affect the amount of excavation. The lateral ditches in most cases follow section lines to avoid cutting up the land into irregular tracts, but it was necessary to locate some of them without regard to land lines. The main ditches are briefly discussed in following paragraphs:

Ditch No. 13.—It is proposed to construct an earth dam, at an estimated cost of \$5,000, across Walnut Lake near the center of sec. 11, T. 10 S., R. 4 W., and to divert the water from the Wells Bayou watershed to Bayou Macon through ditch No. 13. The probable high water in Walnut Lake will be 155.7, which is approximately the same as that under existing conditions. The low-water elevation will not be changed to any appreciable extent. A small earth dam is to be constructed across Caney Bayou in sec. 33, T. 10 S., R. 4 W., at an estimated cost of \$300, to prevent overflow into the district from Eastham Brake. The side slopes of ditch No. 13 are planned to be 1 to 1 except from station 450 (in sec. 12, T. 11 S., R. 4 W.) to station 781 (the end), where side slopes of 2 to 1 are necessary on account of the sandy soil that will be encountered.

Ditch No. 19.—A solid waste bank, to prevent overflow, is necessary at the following points along ditch No. 19: On the east side where the ditch crosses Wells Bayou in sec. 7, T. 10 S., R. 3 W.; on the west side at both crossings of Dry Bayou in sec. 31, T. 10 S., R. 3 W.; and on the west side at Coon Bayou in sec. 6, T. 11 S., R. 3 W. An earth dam, estimated to cost \$1,000, is planned to be constructed across Coon Bayou in the northeast part of sec. 18, T. 11 S., R. 3 W., to prevent high water in ditch No. 19 from flowing to the east. This dam should be constructed with a small sluice gate in order that Coon Bayou may be drained during low water. On account of the sandy soil the side slopes are made 2 to 1 from station 765 (in sec. 19, T. 10 S., R. 3 W.) to station 895 (in sec. 6, T. 11 S., R. 3 W.), and from station 1003 to station 1014 (in sec. 18, T. 11 S., R. 3 W.). The section from station 765 to station 895, where the average depth of cut is about 14 feet and the maximum cut is 21.5 feet (on the bank of Amos Bayou), is estimated at 9 cents per cubic yard. All other excavation on this ditch is estimated at 8 cents. From station 949 to station 1003 (in sec. 7, T. 11 S., R. 3 W.) the ditch follows the channel of Coon Bayou and no excavation is required. The section from station 949 to station 976 must be cleared and grubbed. This work is estimated at \$3,000 per mile. From station 976 to station 1003 the only improvement needed is clearing at an estimated cost of \$2,000 per mile.

The excavation work in ditch No. 19 ends in Bayou Macon on the south line of sec. 28, T. 11 S., R. 3 W. From this point to Macon

Lake the channel must be cleared, at an estimated cost of \$2,000 per mile. In addition, the openings in the banks of Bayou Macon must be closed, especially the channel of Little Bayou Macon. The estimate for this work, based on meager data, is 35,000 cubic yards at 20 cents per yard, or a total expense of \$7,000.

Ditch No. 43.—The soil borings along the proposed route of ditch No. 43 show considerable sand from a point near Wells Bayou to Gum Pond, south of Amos Bayou. The depth of flow through this section is therefore made 8 feet and the side slopes 2 to 1. The difference in elevations of the Wells Bayou basin and the Coon Bayou basin is 10 feet in a distance of $5\frac{1}{2}$ miles. It was impossible to utilize all of this fall on account of the depth of cut that would be encountered in crossing the banks of Amos Bayou and also on account of the erosion that would occur from high velocities in sandy soil. A 6-foot concrete drop is therefore planned at station 750 (in sec. 36, T. 10 S., R. 3 W.) at an estimated cost of \$5,600. An earth dam, estimated cost \$1,000, is planned in Cypress Creek to prevent the water in ditch No. 43 from flowing to the east. At the crossing of Coon Bayou, in the west line of sec. 19, T. 11 S., R. 2 W., a solid waste bank should be made on the east to prevent overflow into Coon Bayou. In addition to the small amount of excavation in Cypress Creek, station 430 to station 458 (in sec. 36, T. 9 S., R. 3 W.), clearing of channel is estimated at \$1,000 per mile.

All excavation in this ditch is estimated at 8 cents per yard except that section from station 600 (at lateral No. 34) to station 700 (in sec. 25, T. 10 S., R. 3 W.), which is estimated at 9 cents. The maximum cut in this section is 20.1 feet, on the bank of Amos Bayou, and the side slopes are 2 to 1.

Ditch No. 81.—The following reaches of ditch No. 81 will require no excavation, but the existing channel must be cleared: From station 155 to station 198 (in sec. 33, T. 9 S., R. 2 W., and sec. 4, T. 10 S., R. 2 W.), and from station 447 to station 760 (in secs. 8–31, T. 10 S., R. 1 W.) in Cypress Creek; from station 781 to station 953 (in secs. 1–14, T. 11 S., R. 2 W.) in Boggy Cut-off and Boggy Bayou; from station 1080 to station 1151+75 (in sec. 26, T. 11 S., R. 2 W.) in Isaacs Lake; and from station 1368+50 (in sec. 14, T. 12 S., R. 2 W.) to station 1700 (in sec. 12, T. 13 S., R. 2 W.) in Boggy Lake. All clearing of channel is estimated at \$1,000 per mile except in Boggy Lake, where it will be light, and is estimated at \$500 per mile. All side slopes are estimated 1 to 1, and all excavation is estimated at 8 cents per cubic yard except the section through Boggy levee, which is estimated at 20 cents. It was assumed that the waste banks were of equal volume on each side of the existing Clay Bayou ditch. In calculating the excavation the end areas of the proposed ditch

through this reach were decreased by an amount equal to one-half the area of the present ditch.

ESTIMATE OF COST.

All the dredge work is estimated at 8 cents per cubic yard except a limited amount in ditches Nos. 19 and 43, which is estimated at 9 cents owing to difficulties of deep excavation. Team work is estimated at 20 cents per cubic yard. The purchase cost of all right of way is estimated at \$20 per acre, and the cost of clearing it is included in the unit cost of excavation. The estimated cost for cleaning channels is \$1,000 per mile, except some light clearing on ditch No. 81 at \$500 per mile and heavy work on ditch No. 19 at \$2,000 and \$3,000 per mile. No estimate of the cost of bridges has been included, for the reason that the State law provides ¹ that drainage districts are not required to pay for the construction of either railroad or highway bridges. The accompanying table of cost contains a summary of all the work necessary for the construction of each ditch, besides the estimate of its cost.

Table of cost.

Ditch No.	Length.		Right of way.		Clearing channel.		Excavation.		Total cost.
	Feet.	Miles.	Acres.	Cost.	Miles.	Cost.	Cubic yards.	Cost.	
1.	28,535	5.40	65	\$1,300			191,500	\$15,320	\$16,620
2.	14,110	2.67	30	600			72,100	5,768	6,368
3.	17,795	3.37	41	820			134,600	10,768	11,588
4.	11,780	2.23	25	500			55,500	4,440	4,940
5.	19,950	3.78	45	900			94,100	7,528	8,428
6.	22,450	4.25	50	1,000			109,600	8,768	9,768
7.	18,790	3.56	45	900			99,100	7,928	8,828
8.	14,570	2.76	35	700			78,000	6,240	6,940
9.	11,790	2.23	25	500			59,600	4,768	5,268
10.	9,700	1.84	25	500			43,900	3,512	4,012
11.	10,800	2.05	25	500			46,700	3,736	4,236
12.	6,770	1.28	15	300			35,500	2,840	3,140
13.	78,100	14.79	470	9,400			2,082,500	166,600	² 2181,300
14.	9,000	1.71	21	420			42,900	3,432	3,852
15.	16,200	3.07	37	740			82,900	6,632	7,372
16.	16,200	3.07	37	740			102,400	8,192	8,932
17.	17,500	3.32	40	800			81,000	6,480	7,280
18.	89,600	16.97	300	6,000			783,300	62,664	68,664
19.	401,500	76.04	747	14,940	³ 49.75	\$100,010	⁴ 3,461,206	283,621	⁵ 406,571
20.	22,700	4.30	52	1,040			131,000	10,480	11,520
21.	8,300	1.57	19	380			43,100	3,448	3,828
22.	16,900	3.20	39	780			92,800	7,424	8,204
23.	204,40	4.62	56	1,120			140,100	11,208	12,328
24.	3,600	1.63	18	360			35,800	2,864	3,224
25.	8,100	1.53	17	340			32,600	2,608	2,948
26.	9,500	1.80			1.80	1,800			⁶ 1,950
27.	5,300	1.00	11	220			22,000	1,760	1,980
28.	5,300	1.00	11	220			22,600	1,808	2,028
29.	19,500	3.70	45	900			99,700	7,976	8,876
30.	11,500	2.18	27	540			60,500	4,840	5,380
31.	11,300	2.14	26	520			51,400	4,112	4,632
32.	29,100	5.51	67	1,340			147,500	11,800	13,140
33.	11,400	2.16	26	520			49,400	3,952	4,472
34.	23,900	4.53	55	1,100			131,000	10,480	11,580
35.	19,900	3.77	46	920			106,000	8,480	9,400

¹ Acts of Arkansas, 1909, Act 279, sec. 28.

² Includes earth dam in Walnut Lake, sec. 11, T. 10 S., R. 4 W., \$5,000, and earth dam in Caney Bayou, sec. 33, T. 10 S., R. 4 W., \$300.

³ Comprises 49.24 miles heavy clearing, at \$2,000 per mile, and 0.51 mile clearing and grubbing, at \$3,000 per mile.

⁴ Includes 672,500 cubic yards deep excavation, at 9 cents per cubic yard.

⁵ Includes earth dam in Coon Bayou, sec. 18, T. 11 S., R. 3 W., \$1,000, and closing openings in banks of Bayou Macon, \$7,000.

⁶ Includes earth dam in Oak Log Bayou, sec. 30, T. 9 S., R. 2 W., \$150.

Table of cost—Continued.

Ditch No.	Length.		Right of way.		Clearing channel.		Excavation.		Total cost.
	Feet.	Miles.	Acres.	Cost.	Miles.	Cost.	Cubic yards.	Cost.	
36.....	24,900	4.72	57	\$1,140	.....	.....	140,300	\$11,224	\$12,364
37.....	24,900	4.72	57	1,140	.....	.....	128,400	10,272	11,412
38.....	20,900	3.96	48	960	.....	.....	105,100	8,408	9,368
39.....	21,000	3.98	48	960	.....	.....	107,300	8,584	9,544
40.....	18,500	3.50	42	840	.....	.....	94,700	7,576	8,416
41.....	14,400	2.73	33	660	.....	.....	76,800	6,144	6,804
42.....	13,300	2.52	30	600	.....	.....	70,400	5,632	6,232
43.....	194,800	36.89	1,500	30,000	0.53	\$530	17,272,200	586,485	² 623,615
44.....	22,400	4.24	.....	.....	.....	.....	104,600	8,368	8,368
45.....	13,200	2.50	.....	.....	.....	.....	69,100	5,528	5,528
46.....	5,300	1.00	12	240	.....	.....	28,300	2,264	2,504
47.....	6,600	1.25	15	300	.....	.....	37,900	3,032	3,332
48.....	5,300	1.00	12	240	.....	.....	38,300	2,264	2,504
49.....	6,600	1.25	15	300	.....	.....	35,200	2,816	3,116
50.....	10,600	2.01	23	460	.....	.....	56,600	4,528	4,988
51.....	15,300	2.90	34	680	.....	.....	82,500	6,600	7,280
52.....	7,900	1.50	19	380	.....	.....	42,200	3,376	3,756
53.....	6,600	1.25	15	300	.....	.....	34,700	2,776	3,076
54.....	12,900	2.44	29	580	.....	.....	66,900	5,352	5,932
55.....	8,100	1.53	19	380	.....	.....	44,400	3,552	3,932
56.....	5,800	1.10	13	260	.....	.....	31,600	2,528	2,788
57.....	8,200	1.55	18	360	.....	.....	42,800	3,424	3,784
58.....	5,300	1.00	12	240	.....	.....	28,800	2,304	2,544
59.....	7,200	1.36	16	320	.....	.....	36,900	2,952	3,272
60.....	4,400	.83	.....	.....	.....	.....	23,900	1,912	1,912
61.....	14,700	2.78	33	660	.....	.....	72,400	5,792	6,452
62.....	17,800	3.37	21	420	1.38	1,380	64,200	5,136	6,936
63.....	4,700	.89	11	220	.....	.....	25,100	2,008	2,228
64.....	7,800	1.48	18	360	.....	.....	41,700	3,336	3,696
65.....	8,900	1.68	16	320	.....	.....	38,800	3,104	3,424
66.....	44,900	8.50	80	1,600	.....	.....	205,600	16,448	18,048
67.....	54,100	10.25	69	1,380	5.71	5,710	207,200	16,576	23,606
68.....	19,600	3.71	44	880	.....	.....	94,100	7,528	8,408
69.....	10,200	1.93	23	460	.....	.....	49,900	3,992	4,452
70.....	14,500	2.75	30	600	.....	.....	78,900	6,312	6,912
71.....	3,920	.74	9	180	.....	.....	21,800	1,744	1,924
72.....	16,000	3.03	35	700	.....	.....	88,600	7,088	7,788
73.....	18,000	3.41	40	800	.....	.....	97,600	7,808	8,608
74.....	35,400	6.70	75	1,500	.....	.....	187,900	15,032	16,532
75.....	45,500	8.62	90	1,800	.....	.....	278,800	22,304	24,104
76.....	74,500	14.11	84	1,680	6.91	6,910	237,000	18,960	27,550
77.....	20,900	3.96	48	960	.....	.....	124,300	9,944	10,904
78.....	17,300	3.28	40	800	.....	.....	113,700	9,096	9,896
79.....	25,000	4.74	55	1,100	.....	.....	180,100	14,408	15,508
80.....	25,500	4.83	63	1,260	.....	.....	143,700	11,496	12,756
81.....	212,270	40.20	735	14,700	³ 17.67	14,530	⁴ 3,137,500	217,376	246,614
Total..	2,226,730	421.72	6,279	125,580	83.75	130,870	22,600,700	1,825,874	2,102,374

Cost of construction, as above..... \$2,102,374
 Contingencies, estimates 5 per cent..... 105,119

Total cost..... 2,207,493
 Number of acres benefited, 294,784.
 Average cost per acre, \$7.49.

¹ Includes 470,900 cubic yards of deep excavation, at 9 cents per cubic yard.

² Includes concrete drop, sec. 31, T. 10 S., R. 2 W., \$5,900, and earth dam in Cypress Creek, sec. 31, T. 9 S., R. 2 W., \$1,000.

³ Includes 6.25 miles light clearing, at \$500 per mile.

⁴ Includes 53,200 cubic yards team work, at 20 cents per cubic yard.

MAINTENANCE.

All drainage channels eventually require attention if they are to maintain their maximum efficiency. The ditches should all be examined at least once every year, preferably just before the rainy season, and all stumps, logs, brush, and other debris which obstruct the channel and retard the flow of water should be removed. No fences, fish traps, or piling should be permitted in the channels. The actual

work necessary to keep the ditches in shape will not be very great if it be attended to each year, but if the ditches are not properly maintained they will deteriorate rapidly and in a few years will require extensive and costly repairs. The officials of the drainage district should provide for regular inspection of all the channels and other construction and arrange to do promptly any maintenance work that may be needed.

A COMPREHENSIVE DRAINAGE SYSTEM NEEDED.

Before Desha County can be developed to any considerable extent, efficient drainage must be obtained. The diversion of Cypress Creek and the closure of the gap in the levee will be the first vital step toward that end, but that will not be sufficient. While it would be possible to do that much by making only one diversion channel along the route considered in the plan of the Mississippi River Commission, the work could not be done economically, it would be of practically no value to the major portion of the district except in such extraordinary floods as those of 1912 and 1913, and it would cost much more than the recommended plan in proportion to the benefits resulting. The construction of ditches Nos. 13, 18, 19, 43, and 81, as described in this report, would not only permit the levee gap to be closed and provide adequate outlet channels for the whole district, but also would permit the immediate improvement of a considerable area along those watercourses. The cost of those five ditches is summarized below:

Cost of ditches.

Ditch No.	Length.	Cost.
	<i>Miles.</i>	
13.....	14.79	\$181,300
18.....	16.97	68,664
19.....	76.04	406,571
43.....	36.89	623,615
81.....	40.20	246,614
	184.89	1,526,764
Contingent expenses, 5 per cent		76,338
Total		1,603,102

While the submains and laterals can be constructed at any time after the main ditches, the cost will be less if the whole project is carried out at once than if a part is deferred. The construction of these smaller ditches will add only 38 per cent to the cost of the five main ditches just enumerated, and in view of the low total cost, estimated at \$7.49 per acre, it is recommended that the construction be continued from the beginning to the completion of the entire system for which the plans have been made.

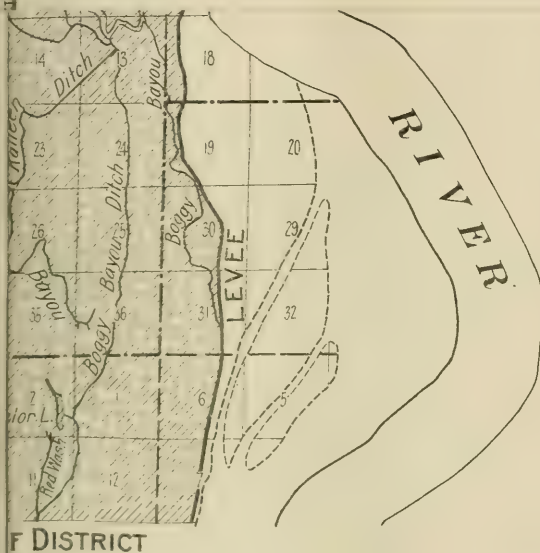


Fig. 2

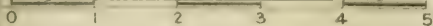
FIGURE BUL. 198 — OFFICE OF EXPERIMENT STATIONS
DRAINAGE INVESTIGATIONS

OVERFLOWED IN 1912 CYPRESS CREEK DRAINAGE DISTRICT DESHA AND CHICOT COS., ARK.

Opening in levee at mouth of Cypress Creek

Prepared to accompany a report
on the Drainage of the Cypress Creek District

SCALE OF MILES





LEGEND

Flood Area shown thus 
 Elevation and Date of Flood Water:  41.0 6-8-12
 Elevations are referred to Desha County Survey Datum
 which is 7.6 ft. below Memphis Datum
 Approximate area flooded - 212,500 Acres

Fig. 2
 U.S. DEPT. OF AGRICULTURE BULL. 138—OFFICE OF EXPERIMENT STATIONS
 DRAINAGE INVESTIGATIONS
AREA OVERFLOWED IN 1912
CYPRESS CREEK DRAINAGE DISTRICT
 DESHA AND CHICOT COS., ARK.
 Overflow due to opening in levee at mouth of Cypress Creek
 Prepared to accompany a report
 on the Drainage of the Cypress Creek District
 SCALE OF MILES


T. 11 S.

T. 10 S.

T. 9 S.

T. 8 S.

R. 5 W.

R. 4 W.

R. 3 W.

R. 2 W.

R. 1 W.



T. 12 S.

T. 13 S.

T. 14 S.

LEGEND

Proposed Ditches	—
Proposed Channel Clearing	—
District Boundaries	—
Watered Boundaries	—
Levee	—
County Lines	—
Township Lines	—
Section Lines	—
Railroads	—
Roads	—
Streams Not Meandered	—
Surface Elevations	—
Bottom Elevations of Streams	—
Elevations of Top of Levee	—
Elevations of Top of Rail	—
Bench Marks	—
Width of Channels	—
Ditch Numbers	—

NOTES—To reduce elevations to Memphis datum add 7.35 feet.

Information on South Lines of Sections 13 to 30 inclusive, T. 14 S., R. 2 W. obtained from Chicot County Drainage District.



Fig. 3

U.S. DEPT. OF AGRICULTURE BUL. 198 — OFFICE OF EXPERIMENT STATIONS

DRAINAGE INVESTIGATIONS

MAP OF CYPRESS CREEK DRAINAGE DISTRICT

DESHA AND CHICOT COUNTIES, ARKANSAS

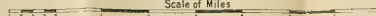
Prepared to accompany a Report on the Drainage of the Cypress Creek Drainage District

by

O. G. Baxter, D. L. Yarnell, and L. A. Jones, Drainage Engineers

1912

Scale of Miles



R. 4 W.

T. 8 S.



T. 9 S

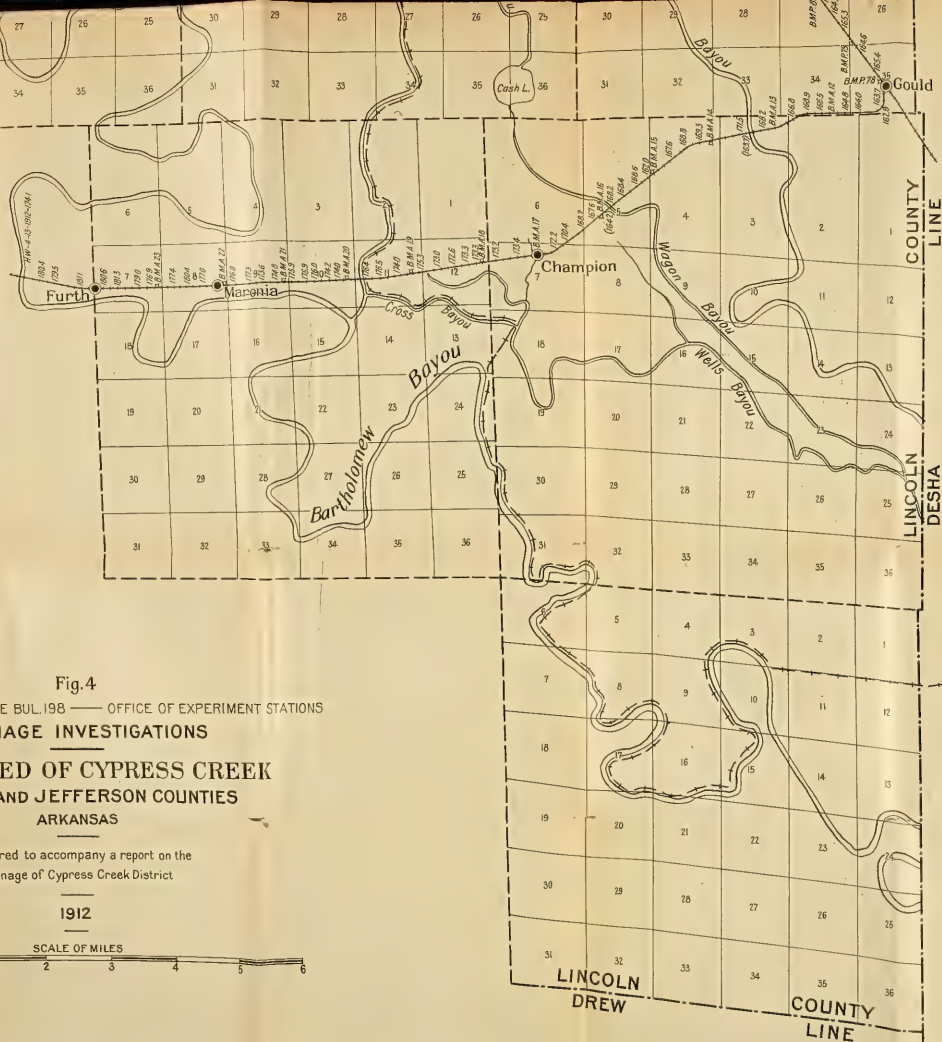
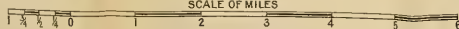
T. 10 S.

Fig. 4
U. S. DEPT. OF AGRICULTURE BUL. 198 — OFFICE OF EXPERIMENT STATIONS
DRAINAGE INVESTIGATIONS
WATERSHED OF CYPRESS CREEK
LINCOLN AND JEFFERSON COUNTIES
ARKANSAS

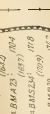
Prepared to accompany a report on the
Drainage of Cypress Creek District

1912

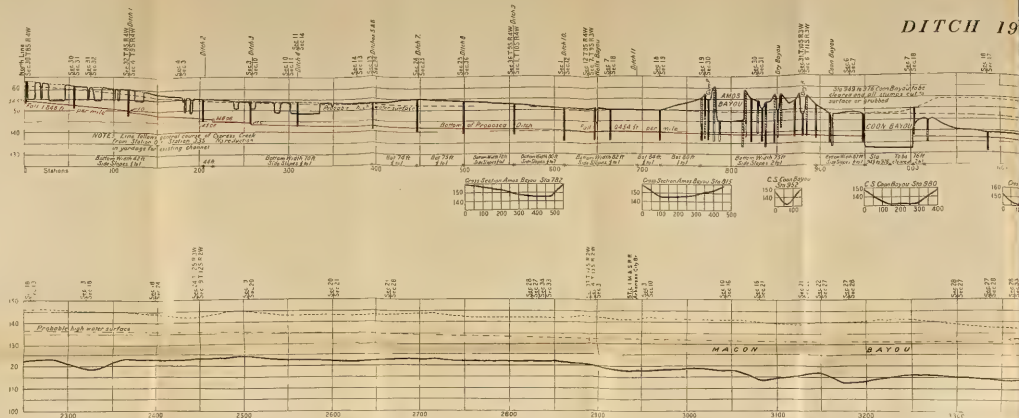
SCALE OF MILES

**LEGEND**

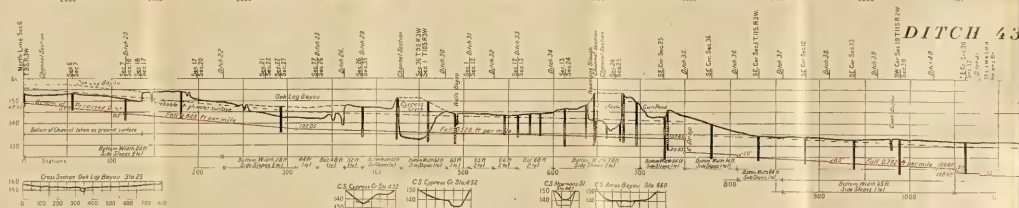
- Watershed Boundary.....
Arkansas River Levee.....
Elevations of Ground Surface.....
Elevations of Bottoms.....
Bench Marks.....



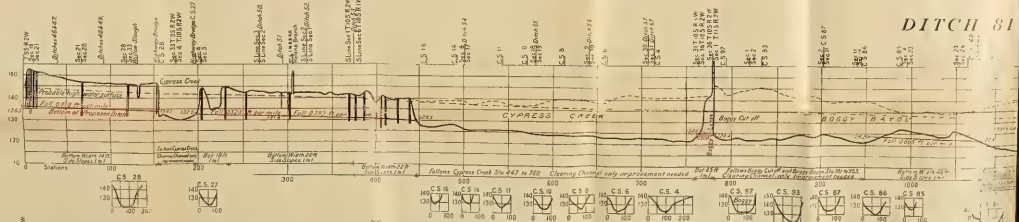
DITCH 19



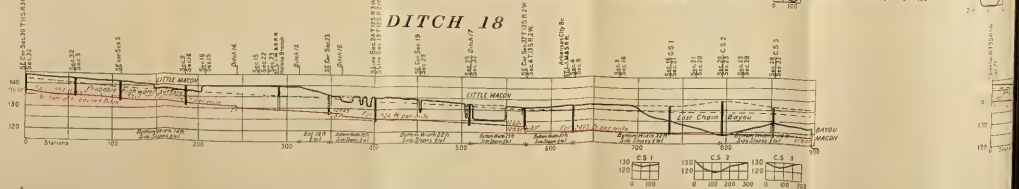
DITCH 43



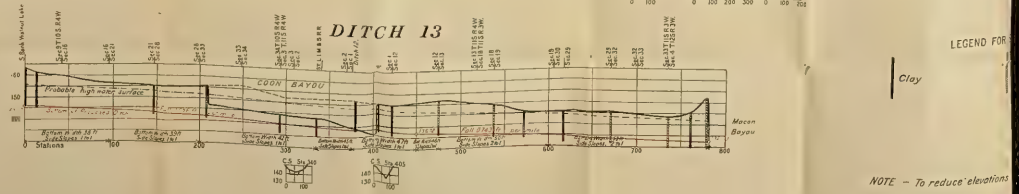
DITCH 81



DITCH 18



DITCH 13



LEGEND FOR

Clay

NOTE - To reduce elevations

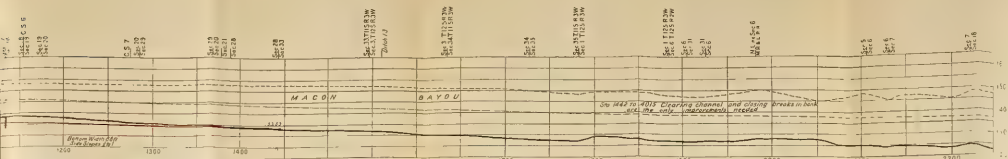


Fig. 6

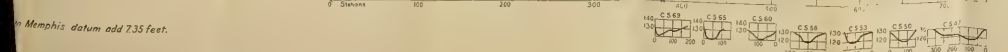
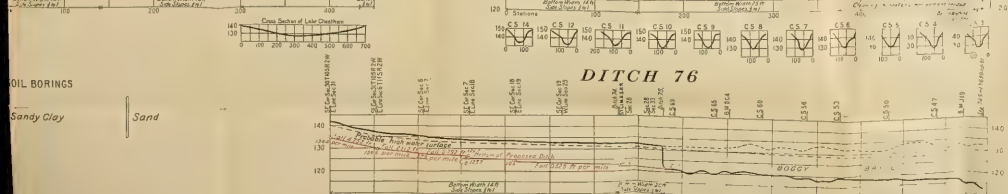
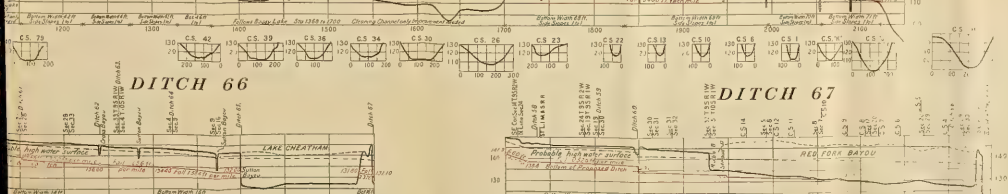
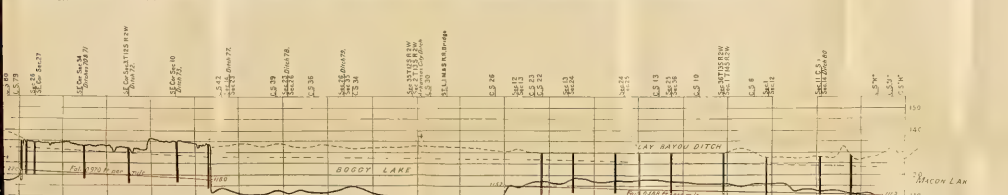
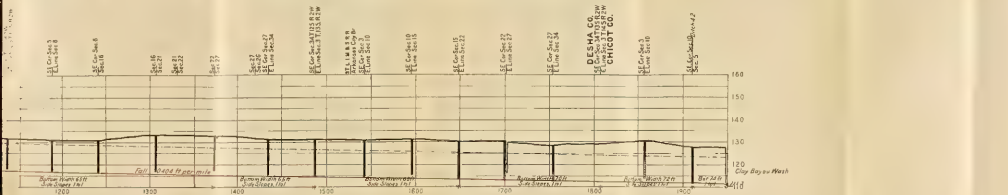
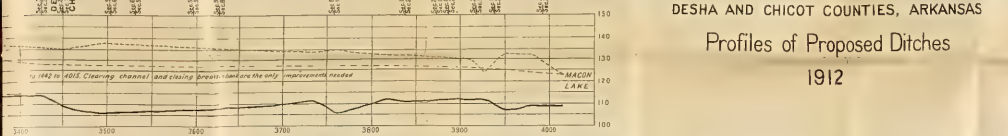
U. S. DEPT. OF AGRICULTURE, BUL. 130 OFFICE OF EXPERIMENT STATIONS
DRAINAGE INVESTIGATIONS

CYPRESS CREEK DRAINAGE DISTRICT

DESHA AND CHICOT COUNTIES, ARKANSAS

Profiles of Proposed Ditches

1912



OIL BORINGS

Sandy Clay

Sand

Memphis datum add 7.35 feet.



BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 199



Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
April 7, 1915.

LOSS IN TONNAGE OF SUGAR BEETS BY DRYING.

By HARRY B. SHAW,

Assistant Pathologist, Cotton and Truck Disease and Sugar-Plant Investigations.

INTRODUCTION.

It is common knowledge that an appreciable loss of weight occurs through the evaporation of the water content of sugar beets, as well as of other fresh vegetables, during storage. In the case of fresh vegetables the actual monetary loss can be measured by the shrinkage in weight. Some of this may or may not be compensated for by an advance in the price of the stored vegetables. With beets it does not follow that the loss in dollars and cents necessarily corresponds to that in weight, because beets owe their value chiefly to sucrose. The sucrose does not pass off with water during evaporation. Yet numerous studies in European beet-growing countries, especially in Germany and France, on sugar beets piled in so-called silos by the growers or stored in the covered sheds of the beet-sugar factories have shown that sugar, while in the beet, is by no means a stable compound. Inversion and decomposition take place. This inversion may be relatively more or less rapid than the loss of water through evaporation, according to the method and duration of storage. Under the present methods of extraction, beets frequently are delivered at the factory much more rapidly than they can be worked up, and they must therefore be stored by the sugar company until the factory is able to handle them. The losses occurring during such storage are recognized by the manufacturer. They do not directly concern the beet grower. One phase of this question does concern the beet grower, but it has hitherto received little consideration and no experimental investigation.

Probably the best practice in harvesting sugar beets is substantially as follows: With a suitable beet plow or digger the beets are

NOTE.—This bulletin takes up the subject of the losses incurred by allowing sugar beets to lie in the field. The data apply specifically to conditions in the Western States, such as Kansas, Colorado, Utah, Nebraska, Idaho, Montana, Nevada, portions of California, and Arizona, but they are equally applicable to the regions having relatively higher humidity.

first torn from their root anchorage and lifted several inches in the soil, which is at the same time loosened. As soon as several rows have been dug, laborers pull the beets entirely out of the ground by hand, throwing those from five, seven, or nine rows into piles at convenient distances apart in the line of the center row. Another squad of laborers immediately follows and tops the piled beets, throwing the tops to one side of the pile of beets. Finally the wagon comes, and the beets are loaded into it and at once hauled to the factory scales. It is thus possible to haul the first load within about an hour after the digging is begun. Most beet growers, however, are not able to organize the work so well. For one reason or another several days may elapse before the beets reach the scales. After the beets are torn from their root system, transpiration still continues, but the water thus lost is no longer replaced by the roots. Evaporation also takes place from the underground portion of the beets in

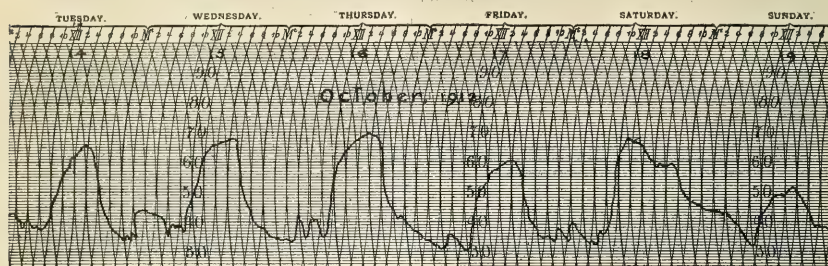


FIG. 1.—Temperature curve, October 14 to 19, 1912, Ogden experiment station, Ogden, Utah.

the now loosened soil. After the beets have been pulled, the evaporation is greatly augmented, whether or not the beets have been topped. Commonly, the beets after being topped are thrown into open piles of no great bulk, remaining there until loaded into wagons. It is obvious that much loss of weight may occur between the digging and the weighing of the beets. The experiments described in this bulletin were carried out to ascertain the extent of these losses.

EXPERIMENTS IN PULLING AND DRYING SUGAR BEETS.

THE DRYING OF BEETS PULLED BUT NOT TOPPED.

At Ogden, Utah, October 17, 1912, the writer dug and pulled several rows of beets. After shaking off the adhering soil these beets were at once weighed and spread on the surface of the ground in the rows from which they had been pulled. They were gathered and weighed again the same evening; then spread out and left until the following morning, when they were weighed for the last time. The mean temperature during this experiment was 43.29° F. (See fig. 1.) The results are given in Table I.

TABLE I.—*Results of drying experiments with sugar beets not topped, at Ogden, Utah, in 1912.*

Date.	Time of weighing.	Weight.	Loss.		Exposure.
			Pounds.	Per cent.	
		<i>Pounds.</i>			<i>Hours.</i>
October 17.....	10.00 a. m.	418			
Do.....	1.50 p. m.	388.25	29.75	7.1	3 $\frac{1}{2}$
Do.....	5.30 p. m.	376.5	11.75	2.8	7 $\frac{1}{2}$
October 18.....	10.00 a. m.	374.75	1.75	.42	24
Total.....			43.25	10.32	

THE DRYING OF BEETS PULLED, TOPPED, AND LEFT IN RATHER SMALL PILES.

On the morning of October 17, 1912, four other rows of beets were dug, pulled, and topped as rapidly as possible. The tops and beets



FIG. 2.—Topped sugar beets in medium-sized piles (in the foreground) and in small piles (in the background), referred to in Tables III and II, respectively.

were weighed separately. The beets were thrown into small open piles (fig. 2) according to a common practice among beet growers, and the tops from the four rows were laid in a single windrow. At intervals the beets and tops were weighed. The mean temperature during this experiment was 50° F. (See fig. 1.) This experiment was repeated on the following day. The loss in weight of beets and tops together was 5.19 per cent. The mean temperature during this experiment was 62° F. (See fig. 1.) The results are shown in Table II.

TABLE II.—*Results of drying experiments with topped sugar beets in small piles, at Ogden, Utah, in 1912.*

Material and date.	Time of weighing.	Weight.	Loss.		Exposure.
			Pounds.	Per cent.	
Roots:		<i>Pounds.</i>			<i>Hours.</i>
October 17.....	10.35 a. m.	232.25			
Do.....	2.15 p. m.	231	1.25	0.54	3 $\frac{3}{4}$
Tops:					
October 17.....	10.20 a. m.	95.5			
Do.....	2.00 p. m.	83.25	12.25	12.8	3 $\frac{3}{4}$
Do.....	5.30 p. m.	74.25	9	9.4	7 $\frac{1}{2}$
Total.....			21.25	22.2	
Roots:					
October 18.....	11.00 a. m.	382.25			
Do.....	5.30 p. m.	373	9.25	2.42	6 $\frac{1}{2}$
Tops:					
October 18.....	11.00 a. m.	185.75			
Do.....	5.30 p. m.	165.5	20.25	10.90	6 $\frac{1}{2}$

On these occasions six rows of beets were used, the tops from the six rows being thrown into one windrow. Since they were more thickly piled, naturally the evaporation was less than in the preceding experiment, in which beets were exposed only during the morning hours, before the maximum temperature had been reached.

THE DRYING OF BEETS PULLED, TOPPED, AND LEFT IN PILES OF MEDIUM SIZE.

On the morning of October 17, 1912, several other rows of beets were dug, topped, and thrown into two piles of medium size after being weighed. (See fig. 2.) These were weighed at intervals, with the results shown in Table III. The mean temperature during this experiment was 43.25° F. (See fig. 1.)

A similar experiment was carried out by Dr. C. O. Townsend, at Garden City, Kans. This was begun on November 10, 1912. These results also are shown in Table III.

TABLE III.—*Results of drying experiments with topped sugar beets in medium-sized piles at Ogden, Utah, and Garden City, Kans., in 1912.*

AT OGDEN, UTAH.

Date.	Time of weighing.	Weight.	Loss.		Exposure.
			Pounds.	Per cent.	
October 17.....		<i>Pounds.</i>			<i>Hours.</i>
Do.....	9.30 a. m.	606			
Do.....	1.30 p. m.	588.25	17.75	2.92	4
Do.....	5.10 p. m.	581	7.25	1.20	7 $\frac{3}{4}$
October 18.....	9.30 a. m.	577.5	3.50	.58	24
Total.....			28.50	4.70	

TABLE III.—*Results of drying experiments with topped sugar beets in medium-sized piles at Ogden, Utah, and Garden City, Kans., in 1912—Continued.*

AT GARDEN CITY, KANS.

Date.	Exposure.	Series 1.			Series 2.		
		Weight.	Loss.		Weight.	Loss.	
			Pounds.	Per cent.		Pounds.	Per cent.
	Days.	Pounds.			Pounds.		
November 10.....		156			139		
November 11.....	1	148	8	5.1	131.5	7.5	5.4
November 12.....	2	140.5	7.5	4.8	121.5	10	7.2
November 13.....	3	128.5	12	7.75	110.5	11	7.9
November 14.....	4	117	11.5	7.37	101.5	9	6.47
Total.....			39	25.02		37.5	26.97

Mean daily loss in weight: Series 1, 6.23 per cent; series 2, 6.74 per cent; of the two series, 6.48 per cent.

In the experiments at Garden City, Kans., the beets were topped as soon as they had been plowed out, and the workers piled them just as in regular field practice. The temperature conditions during these experiments are given in Table IV.

TABLE IV.—*Temperature at Garden City, Kans., November 10 to 14, 1912.*

Date.	Maximum.	Minimum.	Date.	Maximum.	Minimum.
	° F.	° F.		° F.	° F.
November 10 ¹	67	33	November 13.....	53	24
November 11.....	61	10	November 14.....	64	29
November 12.....	31	4			

¹ One-half inch of snow.

THE DRYING OF BEETS PULLED AND PILED WITHOUT BEING TOPPED.

Simultaneously with the experiments at Garden City, Kans., Dr. Townsend caused other series of beets to be thrown into piles without topping them. The results of these experiments are shown in Table V.

TABLE V.—*Results of drying experiments with untopped sugar beets in two piles, Garden City, Kans., 1912.*

Date.	Exposure.	Series 1.			Series 2.		
		Weight.	Loss.		Weight.	Loss.	
			Pounds.	Per cent.		Pounds.	Per cent.
	Days.	Pounds.			Pounds.		
November 10.....		100.5			112.5		
November 11.....	1	95	5.5	5.47	106.5	6	5.33
November 12.....	2	90	5	4.97	100	6.5	5.78
November 13.....	3	80	10	9.95	90.5	9.5	8.44
November 14.....	4	68	12	11.94	81	9.5	8.44
Total.....			32.5	32.33		31.5	27.99

Mean daily loss in weight: Series 1, 8.8 per cent; series 2, 7 per cent; of the two series, 7.9 per cent. The temperature conditions were as shown in Table IV.

THE DRYING OF BEETS PULLED, TOPPED, THROWN INTO LARGE PILES, AND LEFT FOR SEVERAL DAYS.

On October 14, 1912, a plat of sugar beets was dug with a special beet plow. As rapidly as possible the beets were pulled and topped, care being taken to shake off the adhering soil. About 100 pounds of the beets were then thoroughly rinsed with cold water to wash off the remaining soil. They were then spread out on a lawn until their surfaces were dry and again weighed to ascertain the tare. The topped beets were at once weighed and piled in two piles of about 500 pounds each and left uncovered in the open field. The mean temperature during the experiment was 47° F. (See fig. 1.)



FIG. 3.—A pile of sugar beets covered with beet tops to prevent evaporation and a similar pile left uncovered. About 500 pounds of beets are in each pile. (See Table VI.)

They were weighed at intervals, as shown in Table VI. The beets of experiment No. 390 were thrown into two large piles, just as in experiment No. 389, but as soon as piled they were covered with beet tops. Both conditions are shown in figure 3.

TABLE VI.—*The drying of beets pulled, topped, and thrown into large piles, open and covered.*

Series and date.	Time of weighing.	Exposure.	Experiment No. 389; piles left uncovered.			Experiment No. 390; piles covered with beet tops.		
			Weight.	Loss.		Weight.	Loss.	
				Pounds.	Per cent.		Pounds.	Per cent.
Series 1:		Hours.	Pounds.			Pounds.		
October 14	2.30 p.m.		496.25			508.25		
October 15	do.	24	478.50	17.75	3.59	505.50	2.75	0.54
October 16	do.	48	456.00	22.50	4.53	501.00	4.50	.885
October 19	do.	120	421.50	34.50	6.94	487.00	14.00	2.775
Total, 5 days.....				74.75	15.06		21.25	4.180
Series 2:								
October 14	3 p. m.		486.25			458.75		
October 15	do.	24	475.50	10.75	2.21	455.50	3.25	.71
October 16	do.	48	459.75	15.75	3.24	451.25	4.25	.93
October 19	do.	120	417.50	42.25	8.69	436.50	14.75	3.21
Total, 5 days.....				68.75	14.14		22.25	4.85

EFFECT OF DRYING UPON THE SUGAR CONTENT OF BEETS.

At the time these experiments were carried on it was impracticable to make tests of the sucrose content of the beets to ascertain the effect of the evaporation that took place, as indicated in the preceding tables.

After the writer's return to Washington, D. C., some beets were taken from the silo, carefully packed, and expressed to Washington for laboratory tests. These beets were quite fresh and crisp when received.

Eight of these beets were sent to the sugar laboratory of the Bureau of Chemistry on January 15, 1913. From each of them a diagonal core was rasped out for analysis. (Fig. 4.) Each end of

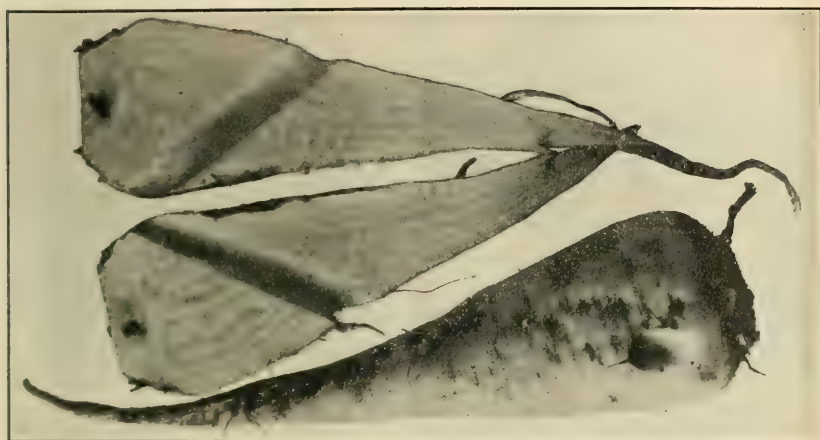


FIG. 4.—Sugar beets, showing the method of rasping out a core from individual beets to make sucrose determinations.

the hole thus made in the beets was immediately plugged with a rubber stopper, the beets being weighed before and after the core had been taken out.

The beets were then returned to the writer, who exposed them to a brisk current of air in a well-lighted room at a temperature ranging from 73° to 77° F. for 4½ hours, in which time the average loss of weight of the eight beets was 3.76 per cent. The beets were again turned over to the sugar laboratory, where a similar core was taken from each beet for test. This was done shortly before noon of the following day. Meantime the beets had been kept in a cool chamber. As will be seen by Table VII, the beets lost as much while in the sugar laboratory before being tested as during the exposure to the current of air.

TABLE VII.—*Analyses of sugar beets made by the sugar laboratory of the Bureau of Chemistry.*

Sample No.	Weight of sample.			Per- cent- age of loss.	Percentage of sucrose.				
	Before boring.	After boring, plus stoppers.	After drying, plus stoppers.		Before drying.	After drying.	In- crease found.	After drying (calcu- lated).	Calcu- lated in- crease.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>						
1.....	865.6	851.2	784.7	7.81	15.20	16.55	1.35	16.49	—0.06
2.....	603.0	600.1	554.7	7.57	16.35	17.00	.65	17.69	+ .69
3.....	853.6	845.3	804.1	4.87	18.80	19.15	.35	19.76	+ .61
4.....	1,082.7	1,066.0	979.4	8.12	10.85	11.05	.20	11.81	+ .76
5 ¹	634.7	625.8	569.7	8.96	12.45	13.80	1.35	13.68	— .12
6 ²	566.6	562.3	513.4	8.70	13.90	14.35	.45	15.22	+ .87
7 ³	540.9	532.9	478.5	10.21	15.55	16.65	1.10	17.32	+ .67
8 ³	864.7	851.9	800.9	5.99	12.05	12.50	.45	12.82	+ .32
Average.....	751.4	741.9	685.6	7.58	14.40	15.13	.74	15.60	+ .47

¹ No. 5 contained decayed spots.² The tips of Nos. 6 and 8 were decayed.³ One of the stoppers of No. 7 was missing when received by the sugar laboratory. This explains the greater evaporation indicated for this beet.

Table VII shows distinctly that the percentage of sucrose increases as the water is withdrawn by evaporation. It also indicates that some inversion and decomposition take place even during so short a period as about 30 hours, the time covered in this series of tests. This inversion would become quite significant if the beets were exposed for several weeks or months, but in its application to the losses that might be sustained by the beet grower by delaying the delivery of his beets after they had been dug and topped for one, two, or three days, it is believed this inversion can be ignored. It will readily be seen, however, that when the farmer is instructed to silo his beets for weeks or months this factor should receive consideration.

THE DRYING OF SUGAR BEETS IN VERY LARGE OPEN PILES.

Sometimes the delivery of beets is too great for the shed capacity of the factory. Farmers are then instructed to store the remainder of their beets until further notice, which may be deferred for several weeks or months. Should the weather not be severe, the farmer may simply pile his beets in large pyramidal heaps in the open field; he may cover them with beet tops or in very cold weather with soil. Commonly he receives from 25 to 50 cents additional per ton for such beets. This, however, scarcely pays for the extra labor involved and takes no account of shrinkage through evaporation and inversion.

An experiment was conducted to ascertain the extent to which evaporation might take place among large piles of beets when the prevailing temperature is comparatively low, as would be expected subsequent to the usual time for harvesting beets.

Arrangements were made with a neighboring sugar company to pile about 50 tons of freshly harvested sugar beets. For this purpose beets were hauled from two farms to the factory yard and carefully weighed. These beets were fairly clean, but representative samples were taken from time to time from which the tare was determined, which was deducted from the bulk lot of beets. The beets were placed in three adjacent piles, as shown in figure 5, containing, respectively, 11 tons 900 pounds, 16 tons 1,700 pounds, and 28 tons 190 pounds, or 56 tons 790 pounds in all. This was done during November 3, 4, and 5, 1912. They were left undisturbed until January 4, 1913, when they were again weighed. During the two months they lost 4.1 per cent. As will be seen from Table VIII, the prevailing temperatures were low, with occasional light showers.

Unfortunately, no tests were made of the sugar content of these beets.



FIG. 5.—Three piles of sugar beets weighing, respectively, 11 tons 900 pounds, 16 tons 1,700 pounds, and 28 tons 190 pounds, or a total of 56 tons 790 pounds, left uncovered in the factory yard from November 3, 1912, to January 4, 1913. The sacks are filled with beet sugar and represent an 11 per cent extraction from each pile. The shrinkage in two months was 4.1 per cent.

The temperature and precipitation conditions which prevailed at the time the experiments were carried on at Ogden, Utah, are shown in Table VIII.

TABLE VIII.—*Temperature and precipitation at Ogden, Utah, from November 1, 1912, to January 5, 1913.*

Day of month.	November, 1912.				December, 1912.				January, 1913.			
	Maximum.	Minimum.	Mean.	Precipitation.	Maximum.	Minimum.	Mean.	Precipitation.	Maximum.	Minimum.	Mean.	Precipitation.
	° F.	° F.	° F.	Ins.	° F.	° F.	° F.	Ins.	° F.	° F.	° F.	Ins.
1.	50	25	37.5	.....	42	18	30	.....	31	10	20.5	.....
2.	54	35	44.5	.....	44	19	31.5	.....	39	10	24.5	.....
3.	42	25	33.5	0.25	44	17	30.5	.....	43	15	29.5	.....
4.	48	30	39	.....	43	10	26.5	0.03	25	17	21	0.10
5.	51	39	45	.14	35	10	22.5	.....	20	5	12.5	.....
6.	61	38	49.5	.....	36	10	23	.....	.....	.....	.....	.....
7.	64	42	53	.....	35	13	24	.....	.....	.....	.....	.....
8.	67	50	58.5	.....	41	17	29	.....	.....	.....	.....	.....

TABLE VIII. — *Temperature and precipitation at Ogden, Utah, from November 1, 1912, to January 5, 1913—Continued.*

Day of month.	November, 1912.				December, 1912.				January, 1913.			
	Maximum.	Minimum.	Mean.	Precipitation.	Maximum.	Minimum.	Mean.	Precipitation.	Maximum.	Minimum.	Mean.	Precipitation.
	° F.	° F.	° F.	Ins.	° F.	° F.	° F.	Ins.	° F.	° F.	° F.	Ins.
9.....	57	35	46	0.26	45	12	28.5					
10.....	47	24	35.5		43	15	29					
11.....	47	24	35.5	.02	47	17	32					
12.....	52	26	39		47	21	34					
13.....	55	28	41.5		51	24	37.5					
14.....	53	29	41		52	24	38					
15.....	53	28	40.5		42	24	33					
16.....	55	25	40		34	20	27					
17.....	56	27	41.5		38	19	28.5	0.27				
18.....	55	28	41.5		41	20	30.5					
19.....	57	33	45	.04	34	4	19					
20.....	47	21	34		32	7	19.5					
21.....	47	23	35		28	3	15.5					
22.....	51	26	38.5		30	5	17.5					
23.....	52	23	37.5		35	15	25					
24.....	48	21	34.5		34	16	25					
25.....	48	19	33.5		34	7	20.5					
26.....	46	20	33		35	16	25.5					
27.....	49	23	36		34	11	22.5					
28.....	45	21	33		33	13	23					
29.....	52	29	40.5		41	26	33.5	.07				
30.....	39	16	27.5	.20	39	19	29					
31.....					40	20	30	.04				
Mean or total.....			39.7	.91			27.1	.41			21.6	0.10

Mean for entire period, 36.72° F.

RELATION OF SHRINKAGE TO MONEY LOSS.

The answer to the question whether the shrinkage of sugar beets involves a corresponding money loss to the growers will depend on the system of payment for the beets. There are two methods in vogue in many districts; in others, only one. In most cases the farmer has the option of contracting to furnish his beets to the factory either at a flat rate per ton for all beets containing above the stipulated minimum of sucrose or he may accept a sliding scale of payment whereby the price per ton is modified according to the actual average sucrose content of his beets. Some sugar companies offer a so-called sliding scale, which is in reality two separate flat rates, one for all beets up to a certain percentage of sucrose, and a slightly higher rate for all above that percentage. Only the flat rate, properly so called, and the sliding scale will be discussed.

The following is a fair example of prices under the sliding scale:

Five dollars for beets containing 16 per cent of sucrose and 30 cents a ton for every additional 1 per cent of sucrose, with a deduction of 25 cents a ton for every 1 per cent less than 16 until the acceptable minimum is reached.

Under this system it will be seen that the increment of sucrose is paid for at practically the same rate per cent as the basal price of

\$5 for 16 per cent beets. Fractions of 1 per cent are paid at the same rate.

An example of the flat rate would be \$5 a ton for all beets testing 14 per cent of sucrose or more.

It is at once evident that any ordinary loss in weight due to a delay of one day or several days between digging and weighing is, under the sliding scale, reasonably well compensated for, and that the loss in that time due to inversion or decomposition is practically negligible, provided the sucrose test is made from beets taken when they are delivered and weighed and not from a sample taken from the field just before or immediately after the crop is dug.

The sliding scale would probably also be fairly equitable in dealing with beets that have been piled under the sugar company's instructions for one or two weeks, but after such a time continued shrinkage in weight would mean a money loss to the grower, because an appreciable inversion of sucrose would become concurrent with the loss in weight. In Germany and other European countries this circumstance has been met by adding 1 per cent to the indicated sugar content at the time of delivery for each month the beets have been stored at the request of the sugar company.

The farmer who, whether or not from choice, accepts the flat rate sustains an actual money loss corresponding to the shrinkage in tonnage through evaporation. He is paid according to the net weight of his beets at the time they are weighed on the factory scales. Let us say that a good beet grower obtains a yield of 20 tons an acre and agrees to accept a flat rate of \$5 a ton. This equals \$100, gross receipts, an acre. It has been shown that an average daily shrinkage of 6.48 per cent (or 6.5 per cent in round numbers) may occur when handling the beets in the ordinary manner. Frequently the writer has seen beets left several days in the field after they had been dug. This means a loss of \$6.50 a day per acre. Should the farmer have no alternative but to accept the flat rate and at times find that delay in getting his beets weighed is unavoidable, he may effect a considerable reduction in evaporation from his beets by leaving them in relatively large piles and still further by covering the piles with beet tops. This may be done very easily and rapidly if the system of harvesting outlined in this paper be adopted. It would be quite practicable to gather the beets into piles even larger than those mentioned in Table VI, which averaged about one-fourth of a ton. If handled in the manner already described, the tops would lie beside the beets and be at once available for covering the latter without further labor in collecting them.

It is seen that the average daily shrinkage during five days in the large uncovered piles was 2.92 per cent; in the covered piles this loss

was reduced to 0.9 per cent a day. On the other hand, when the beets are thrown into small piles or are left scattered along the rows from which they were pulled, the shrinkage increases greatly, reaching 4.7 per cent in 24 hours in the Utah experiment and an average of 6.48 per cent a day for four days in the experiment of Dr. Townsend in Kansas. (Table III.)

These data apply to conditions in the Western States, such as Kansas, Colorado, Utah, Nebraska, Idaho, Montana, Nevada, portions of California, and possibly Arizona. In the Central and Eastern States it is believed that the loss from evaporation would not be quite so much, owing to the greater relative humidity of the atmosphere in those States.

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May 4, 1915.

A MAGGOT TRAP IN PRACTICAL USE; AN EXPERIMENT IN HOUSE-FLY CONTROL.

By R. H. HUTCHISON, *Scientific Assistant.*

INTRODUCTION.

During the season of 1913 experiments were carried out independently by Levy and Tuck at Richmond, Va., by C. G. Hewitt at Ottawa, Canada, and by the writer at Arlington, Va., and New Orleans, La., all of which agreed in demonstrating a most pronounced migratory habit in house-fly larvæ just before pupation. It was found very easy to trap them at this particular stage of their development, and experiments with small maggot traps showed that as high as 98 or 99 per cent of the larvæ could be caught. At the suggestion of Mr. W. D. Hunter the writer has made an attempt during the past season to apply the principles of the maggot trap to practical use and to test its efficiency when used to destroy the maggots in large masses of manure. In this article are reported the results obtained from experimental work along this line, conducted at the Maryland Agricultural College at College Park, Md. Dr. H. J. Patterson, president of the college and director of the experiment station, has been most generous in his cooperation in this work, and through him the materials and labor for the construction of the trap were supplied. The writer wishes also to acknowledge the helpful suggestions of Profs. T. B. Symons and E. N. Cory, of the college.

LOCAL CONDITIONS WITH REGARD TO FLY PREVALENCE AND BREEDING PLACES.

The college was selected as a suitable place for conducting the experiment, partly because the conditions with regard to breeding places for flies seemed such that it would be easy to determine whether or not the maggot trap was effective. The college is some-

NOTE.—This bulletin describes the operations of a maggot trap based on the migratory habit of house-fly maggots just before pupation. It will be of interest to all farmers and to those industries in which the accumulation of refuse may encourage the propagation of the house fly.

what isolated by its position on a hill and separated a considerable distance from any near-by stables. On the accompanying map (fig. 1), which has been adapted from a map of the Geological Survey, is shown the topography of the surrounding section. The location of only two of the college buildings is given, viz, the college kitchen (K) and the stable (S). The college kitchen, by reason of odors from cooking and the presence of large quantities of garbage kept in iron pails just outside the door, attracted extremely large numbers of flies. One could not approach these garbage pails without stirring up a noisy swarm which had congregated there. However, no flies were breeding out from this garbage, for the reason that it was

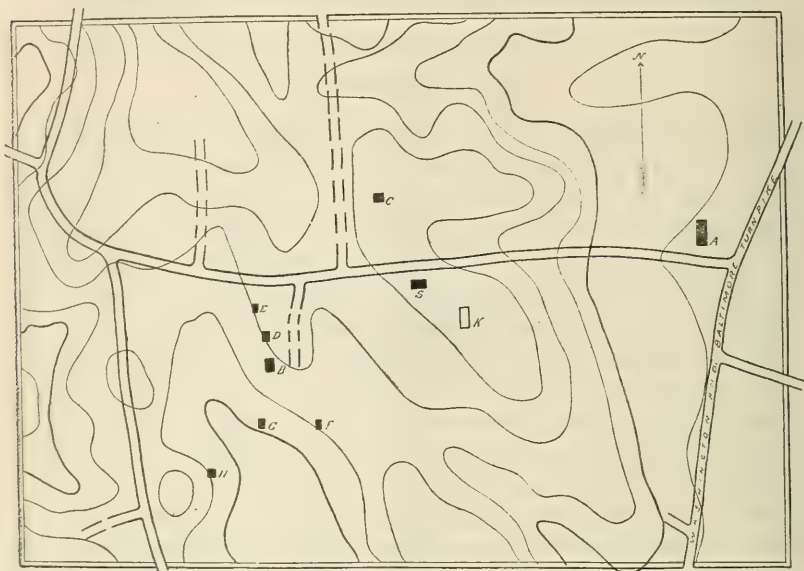


FIG. 1.—Map of vicinity of the Maryland Agricultural College showing the location of the college kitchen (K), the stable (S), and the proximity of other breeding places of flies (A, B, C, D, etc.) (Original.)

entirely removed every two or three days and taken to a near-by farm, where it was fed to hogs.

The breeding ground nearest to the kitchen was the pile of manure heaped just outside the college stable. This is nearly 200 yards northwest of the kitchen. It is probable that a large majority of the flies at the kitchen came from this source. Upon examination at various times during June and July the fresher portions of this heap were always found heavily infested with larvæ. Puparia were also found in great abundance in the loose soil and in the manure at the periphery of the pile. Three horses were kept in this stable, and two of them were standing in the stalls during the greater part of each day. Flies were also very numerous in and about the stable, and during the day the horses were continuously tormented by them.

With the exception of the college stable, there were no breeding places for flies within 400 yards of the kitchen. The stable, indicated by the letter C on the map, is approximately 400 yards from the kitchen and about 200 yards from the college stable. Other stables are located some 400 to 500 yards west of the college stable, the distance from the kitchen being about 100 yards greater.

Another extensive breeding place was found in the large collections of manure at the barns of the experiment station, located about 700 yards northeast of the college. This is indicated on the map by the letter A.

PLAN OF EXPERIMENT.

With these conditions prevailing, it was planned to construct a maggot trap large enough to take care of the entire manure production at the college barn, with the idea that if the trap proved effective there should appear a marked decrease in the prevalence of flies, not only at the barn but at the college kitchen. To determine whether or not the trap was effective the following three lines of observation were undertaken: (1) By collection and careful estimate of the larvæ caught by the trap and subsequent search for puparia in the manure, to get some idea of the percentage destroyed; (2) by making numerous fly counts during the season to find out whether the prevalence of flies at the kitchen and stable was decreased; and (3) to determine whether any of the flies at the college came from nearby breeding grounds (A, B, C, etc.) other than the manure heap at the college stable.

THE MAGGOT TRAP. ●

The maggot trap used in this experiment was designed and constructed as follows. First, a concrete floor was prepared 22 feet long and 12 feet wide. Around this floor was a rim or wall of concrete 4 inches high and 4 inches thick. An outlet pipe 4 inches in diameter was fitted in one corner toward which the floor sloped a little so that water would run out easily. Water was retained in the concrete floor by stopping the pipe outlet with a plug of soft wood. The pipe outlet led to a small cistern 5 feet square and 4 feet deep, the walls and floor of which were made of concrete. Standing on the floor of the concrete basin was constructed a wooden platform 20 feet long and 10 feet wide, supported on legs 1 foot high. The framework of the platform was made of 2 by 4-inch studding. There were 6 of these pieces running lengthwise 2 feet apart, and one fastened across each end. Each of the long pieces was supported on four legs set at intervals of nearly 7 feet. Across the top of the framework were nailed strips 10 feet long by 1½ inches thick and 1 inch wide. These strips were nailed 1 inch apart. Plate I shows most of the details

of construction. Plate II gives another view, including also the outlet pipe (in this case consisting of 4-inch terra cotta) and the pump in place over the cistern. On account of various obstructions it was necessary to place the cistern some distance away from the trap, although, as will be pointed out later, it is desirable to have the cistern close to the trap and the pump so arranged as to return the contents of the cistern to the manure heap on the platform.

THE METHOD ADOPTED IN USING THE MAGGOT TRAP.

The maggot trap was put into operation on July 25. On this date the manure pile which had accumulated in front of the barn during June and July was hauled away and spread on the fields, so that, beyond the hatching out of the pupæ and larvæ already present, it ceased to exist as a breeding ground for flies. On and after July 25 each day's production of manure was heaped on the platform. Beginning at the end farthest from the barn door, the manure was piled up to a height of from $3\frac{1}{2}$ to 4 feet. The heap was maintained at about this height, and with the daily additions it kept increasing in length. Plates I and II show the appearance of the heap after a little more than four weeks' accumulation. The platform was found large enough to hold a little more than two months' production of manure from three horses and could easily have been made to hold the total production for three months by making the pile higher. Each day, after the addition of manure and litter from the stable, the manure on the platform was sprinkled with enough water to moisten it thoroughly without causing any leaching. Water was run into the concrete basin below the platform, so that the floor beneath the manure was covered to a depth of $\frac{1}{2}$ inch in the shallowest part. Larvæ migrating from the manure dropped into the water below and were drowned.

At least once a week, and sometimes oftener, the water was drawn off from the basin into the cistern and the floor was washed clean by a strong stream of water from a hose. The larvæ which had fallen into the water, together with the débris which had sifted through the platform or fallen from the sides, were collected at the cistern end of the outlet pipe in a strainer. The matter thus retained in the strainer was then spread out on a smooth concrete surface near by, and the number of larvæ present was carefully estimated. The outlet was then plugged, and the basin again partly filled with water by pumping back what had run into the cistern.

THE PERCENTAGE OF MAGGOTS DESTROYED.

Without going into details of the weekly or biweekly counts, it will be enough to state that during the period from July 25 to October 1 a total of about 112,000 dead larvæ were collected in this way.

But this number does not represent all that dropped out of the manure into the water below. A flock of young turkeys roamed at large during the summer over the college grounds and adjoining fields. Having once found the maggot trap they made frequent visits and were seen to devour the larvæ with great avidity, sometimes completely clearing the floor except where the water was more than 2 or 3 inches deep or when it was so badly discolored as to conceal the larvæ. Sparrows also were seen frequently on this floor, but one could never get close enough to see whether they actually devoured any larvæ or not. It is more than likely that they did. The actual number of larvæ which were destroyed by the maggot trap was undoubtedly much greater than 112,000.

After October 1 the writer and an assistant examined all the manure on this platform in search of puparia. The manure was thrown off, a few bushels at a time, onto a smooth concrete surface near by and very carefully examined, all straw being shaken out and all solid parts being finely broken up. In a very literal sense this was like looking for a needle in a haystack. A few scattered puparia were seen in various parts of the heap, but in only two spots were they to be found in the characteristic clusters or "nests" which can be found so readily at the edges of manure piles on the ground. These two nests were found at the end of the platform where the most recent additions had been made. The manure at this end had not been sprinkled with water after the day it was put on. Failure to keep this moist as long as larvæ were present is, in the writer's opinion, the explanation of the pupation in this part. One nest contained about 400, and the second about 700 puparia. Allowing for some that may have escaped notice, the number of puparia may be given in round numbers as 1,500. No larvæ whatever were found in any part of this heap, the oldest part of which had been on the platform for two months, and even the freshest portion of which had been standing for at least 10 days before it was examined. If, then, 1,500 represents the total number which pupated in the manure and 112,000 the number which was destroyed by drowning, it shows a percentage destruction of about 98.5 per cent of the possible total. This is illustrated in figure 2, above. Taking into account the larvæ devoured by turkeys, etc., it is probable that the effectiveness of the trap could be rated as above 99 per cent.

In a former bulletin the claim was made that manure will be practically free from maggots after standing 10 or 12 days. Special attention was given to this point during the course of the experiment, and all observations tended to support the claim. Moreover, there was no evidence that larvæ ever migrated from the fresher portions of the manure to the older parts to pupate. That old manure does not serve as a breeding place for flies is a point that deserves

some emphasis entirely aside from its bearing on the practical use of the maggot trap. The explanation is probably to be found in the changes which take place in the manure heap during storage. As the pile stands it settles considerably, with a consequent decrease of air spaces, and, especially if watered, air does not penetrate far below the surface. Dehérain and Dupont (1900) have shown that in manure well heaped so that air can not penetrate readily, the confined gases consist largely of carbon dioxid and methane, and that oxygen is not found except near the surface. It may well be that the lack of oxygen and the abundance of carbon dioxid render old manure unfavorable for the breeding of flies. It may also be that the composition of the gases in the manure is one of the factors which influence migration and the choice of a place for pupation.

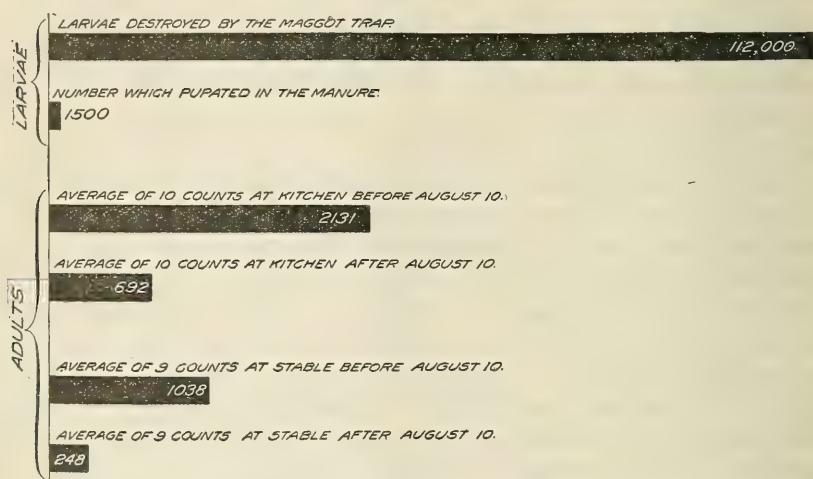


FIG. 2.—Graphical representation of the work of the maggot trap and its effect on the prevalence of flies. (Original.)

EFFECT ON THE FLY PREVALENCE AT THE STABLE AND KITCHEN.

Turning now to the second line of observation, it will be of interest to determine to what extent the maggot trap influenced the number of flies at the stable and kitchen. An answer to this is to be found in the series of fly counts made during the season, both before and after the trap was started. In taking these counts "tanglefoot" sticky fly paper was used. The papers were exposed for 24-hour intervals and counted immediately at the end of that period. Figure 3 is a graphic representation of these series of counts at the stable and kitchen. In each case the number given is the total caught on two papers exposed at the same time. At the kitchen the two papers were always exposed in the same way on top of the garbage pails, and at the stable one paper was put on the floor just outside the

door and the second just inside the door, which faces the east. On several occasions papers were exposed, but the counts are not given in the diagram for the reason that a shower of rain or a strong wind spoiled some of the papers. The numbers which are plotted are those obtained on clear, warm days, on which the climatological conditions were nearly the same except for the direction of the wind. This will account for the irregular time intervals between the successive counts.

It is recognized that this method is not all that could be desired as an accurate index of fly prevalence. The use of a small number of fly papers in this way is nothing more than a method of sampling, but since the papers were exposed always in the same places and under nearly the same climatological conditions, the method may be considered as reliable as any method of sampling used in other lines of

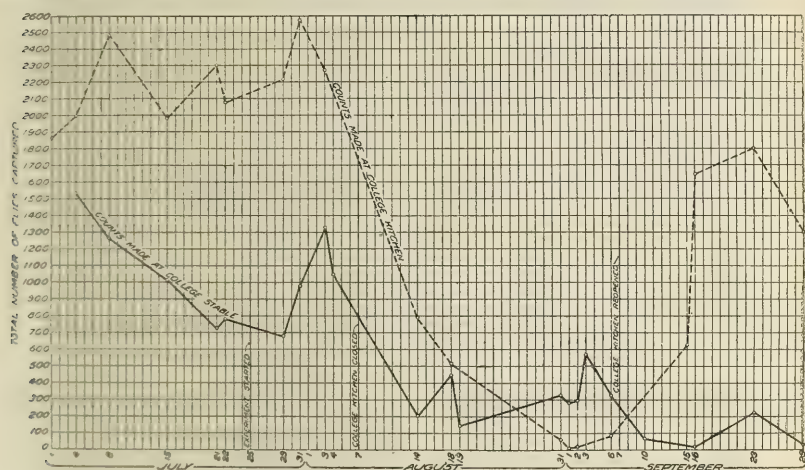


FIG. 3.—The broken line connects series of fly counts at the garbage pails near kitchen; the solid line, those at the stable. (Original.)

work. The use of a few fly papers in this way would not of itself have any appreciable effect on fly prevalence. It was thought that the use of fly traps would complicate the situation in that any apparent reduction in the number of flies might be ascribed to their use rather than to the maggot trap.

A study of the fly counts shown in figure 3 reveals that there was a decided drop in the number of flies both at the kitchen and stable very shortly after the maggot trap was put into operation. Assuming that all the flies at the stable and kitchen at the time the experiment began (July 25) were freshly emerged and that they would all die off within three weeks (there is some evidence that flies seldom live longer than this in midsummer), one would expect to find a reduction in the number of flies about August 10 or 12. As a matter of fact this is what occurred. Although the counts fluctuate considerably after

this date, in no case do the highest counts rise to the level of the lowest counts made before August 10.

In one respect these counts hardly give a fair indication of the effect of the maggot trap, this for the reason that the college kitchen was closed from August 7 to September 7. It will be seen that flies almost completely disappeared from the kitchen during the latter part of August, but as soon as the garbage pails were again in use the fly counts go up fairly high, although not as high as the lowest count at this place before the experiment started. It is interesting to note that while the kitchen was closed the fly counts at the stable were somewhat increased and that after the kitchen reopened the flies almost disappeared from the stable. Taking the counts at the kitchen, we find that the average of the 10 counts before August 10 is 2,131, while the average of the 10 counts after August 10 is 692, an average reduction of 67.5 per cent. At the stable the average of 9 counts before August 10 is 1,038, and the average of 12 counts after August 10 is 248, an average reduction of 76 per cent.

The behavior of the horses standing in the stalls was also a fairly good index of fly prevalence in the stable. As noted above, the horses were constantly tormented during June and July. During the day the stamping of feet and switching of tails was incessant. After the maggot trap had been in operation for some time there was a noticeable change. The horses stood much more quietly, and their efforts to get rid of flies were less continuous. Several men at the college observed this and volunteered the information.

INFLUENCE OF OTHER BREEDING PLACES ON THE NUMBER OF FLIES AT THE COLLEGE.

If the maggot trap was really destroying 98 per cent of the flies breeding in the manure at the college stable, why is there not a corresponding reduction in the number of adult flies instead of an average reduction of from 67 to 76 per cent? The third series of observations points to a probable explanation of this. As indicated on the map, there are several breeding places within 700 yards of the college, and 700 yards is well within the range of flight of flies, a fact which has been proved by several workers. A few flight experiments with marked flies were carried out during the season, not with the idea of determining the range of flight, but merely to make sure whether or not flies from these various breeding places found their way to the college stable and kitchen.

First, about 600 recently emerged flies were thoroughly dusted with finely powdered red crayon and liberated on August 31 at a point near the stable indicated by the letter B (fig. 1). The point of liberation was about 400 yards west of the college stable and perhaps 500 yards from the kitchen. In spite of the presence of several houses



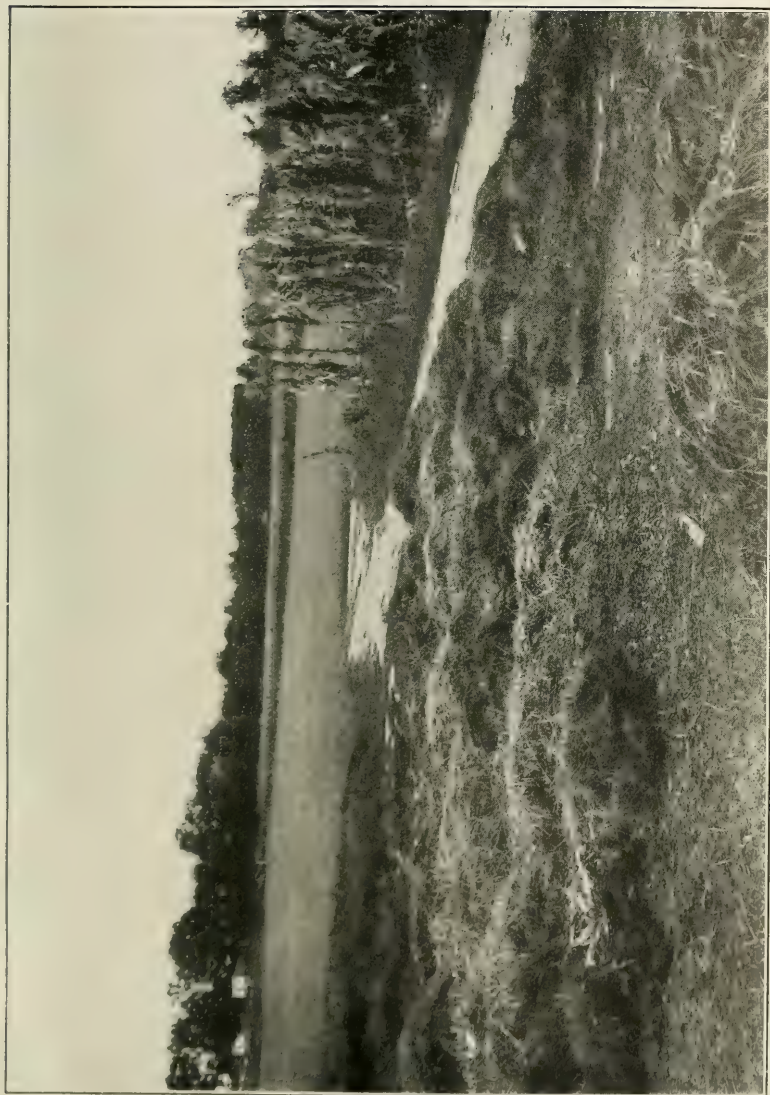
A MAGGOT TRAP FOR HOUSE-FLY CONTROL.

View of the maggot trap, showing the concrete basin containing water in which larvae are drowned, and the wooden platform on which manure is heaped. (Original.)



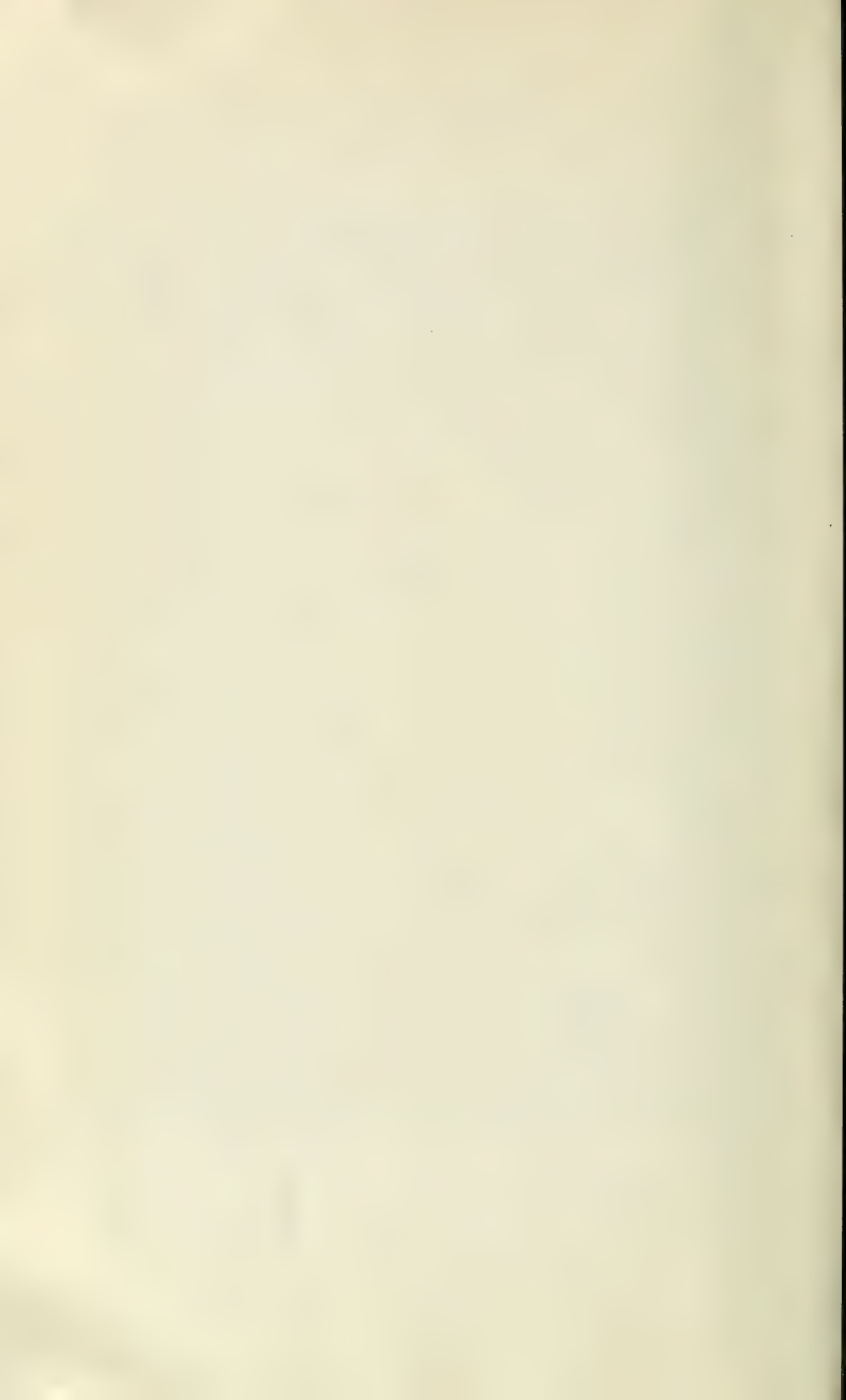
A MAGGOT TRAP FOR HOUSE-FLY CONTROL.

Another view of the maggot trap, showing the pipe leading to the small cistern, and the pump used to force water back to the concrete basin. (Original.)



UNDESIRABLE CONDITIONS WHICH ARE OVERCOME BY USE OF THE MAGGOT TRAP.

A manure pile covering a large area and having little depth. Illustrating the conditions which favor the greatest loss of nitrogen, and at the same time offer the best breeding ground for flies. (Original.)



and stables in the immediate vicinity, some of these marked flies found their way to the college barn. Here two of this lot were recovered within the first 24 hours, and a third one during the third 24-hour period. That no flies were recovered at the kitchen is to be explained by the fact that the kitchen was closed and there was nothing there to attract flies.

A second lot of about 500 flies, sprayed with rosolic acid, were liberated at the dairy barn (A) of the experiment station, 700 yards due east from the college stable. The distance from the kitchen is slightly less. They were liberated at 3.30 p. m. September 1. On September 3 two marked flies were found on papers exposed at the dairy barn, but none was recovered at the college stable or kitchen. A strong southwest wind was blowing at this time and may have had some influence on the result. It is hardly to be doubted that when the kitchen is in use numbers of flies from this source are attracted to it. The manure pile back of the dairy barn was found to be heavily infested at all times during the summer, and flies bred out here by the thousands.

In a third experiment about 800 flies marked with powdered red crayon were liberated on September 15 at the stable marked by the letter C (fig. 1). Within the first 24 hours 11 marked flies were recovered on fly papers at the garbage pails, and two more during the second 24-hour period after liberation. No marked flies were recovered at the college stable in this experiment. The kitchen was in use at this time, and it must be considered significant that the flies were recovered only at the kitchen, although they had to pass right by the stable. This indicates the sharp rise in fly counts at the kitchen when it reopened in September.

The same thing happened on September 22. A lot of about 600 flies sprayed with rosolic acid had been liberated on September 21 near the stable marked on the map by the letter D (fig. 1). None of these were recovered at the college stable, but three were found within the first 24 hours on papers exposed on the garbage pails at the kitchen.

These few experiments indicate that a large number of the flies which congregate at the college kitchen and stable come from near-by breeding grounds other than the manure pile at the college barn. And it may be said that a reduction of from 67 to 76 per cent in the average number of flies, in spite of the proximity of these other breeding places, speaks well for the efficiency of the maggot trap.

SOME DEFECTS OF THE MAGGOT TRAP.

The experience during the past season with the platform maggot trap has directed attention to certain defects in its practical working. These defects, however, are not of such a serious nature that they

can not be overcome. In the first place, some trouble resulted from smaller particles of manure sifting through between the cross strips and accumulating in the water below. This was especially the case when sawdust and shavings were used for bedding instead of straw. If this material were allowed to accumulate there would finally be enough of it to provide a breeding place on the concrete floor, where the maggots should be killed by drowning. Much of this sifting could be prevented by placing the cross strips closer together, so that only $\frac{1}{2}$ -inch or even $\frac{1}{4}$ -inch spaces were afforded. It is not at all likely that $\frac{1}{4}$ -inch spaces would interfere with migration; but in spite of such improvement there would be, even with the most careful handling, a certain amount of straw or small particles of manure which would fall from the sides of the heap or from the fork at the time it was put on the platform. It will always be necessary to clean out the concrete floor more or less regularly, and for this purpose a long-handled stable broom will be satisfactory when the water supply does not permit the use of a strong stream from a hose. To facilitate the cleaning of the floor the platform should not be less than 1 foot high nor more than 10 or 12 feet wide. The solid matter which happens to be washed into the cistern will decompose in time and be pumped back with the liquid onto the manure heap.

In dry weather evaporation of the water on the concrete floor will leave large areas of floor surface dry. Larvæ falling from the manure above onto the dry floor will crawl away and can crawl up the vertical sides of the surrounding rim; in fact, they could crawl up this surface even if it were as smooth as glass. To insure that all larvæ are drowned it is necessary to keep this in mind, and every day, when the manure is added to the heap, more water can be supplied if necessary. This operation will consume very little time.

The most serious defect was found in the fact that mosquitoes bred very freely in the water standing in the concrete basin and in the cistern. In order not to have one pest multiplying at the expense of another, it is necessary to run all water out of the concrete floor at least once a week and to clean the floor at this time; if then a little oil is poured over the surface of the liquid in the cistern, mosquito breeding will be prevented entirely. This method was used during the last weeks of the experiment with satisfactory results. If the cistern were carefully and tightly covered, perhaps the use of oil would not be necessary.

No counts or estimates were made of the larvæ destroyed during October and November. It is known, however, that larvæ continued to appear in the water on the floor during the most of October and during the warmer parts of November. On December 10 the manure was examined without removing it from the platform, and therefore

not as thoroughly as on the former occasion, but there were found at the fresher end of the pile at least four nests of several hundred puparia each. It is not possible to estimate the percentage destroyed, but it was quite plain that the trap was not as effective during the autumn as in the summer. This may have been due partly to carelessness in the matter of watering the heap, but more probably to the lower air temperatures of this period. When the outside temperature is low, the difference between the air and the temperature of the manure heap is so great that the larvæ will not leave the heap; and if the low temperatures prevail for a long period the larvæ will eventually pupate in the manure. The following experiment shows the effect of low air temperature. This experiment was conducted at New Orleans, La., in December, 1913. A small wire basket was filled with fresh horse manure on December 1 and was continually exposed to flies. The number of larvæ caught and the temperature during the period are tabulated below.

Experiment to show effect of low air temperature in preventing migration of house-fly larvæ, New Orleans, La., December, 1913.

	Number of larvæ caught.	Mini- mum tempera- ture.	Maxi- mum tempera- ture.	Mean tempera- ture.
		° F.	° F.	° F.
Dec. 2.....	12	57	74	65.5
3.....	15	56	67	61.5
4.....	47	57	68	62.5
5.....	199	56	73	64.5
6.....	745	57	70	63.5
7.....		48	61	55
8.....	¹ 4,000	40	61	55
9.....	0	32.5	50	41.7
10.....	1	34.5	56	45.3
11.....	43	38	59	48.5
12.....	465	41	65	53
13.....	¹ 900	47	68	53
14.....		58.5	73	65.8
15.....	¹ 700	49	66	57.5
16.....	115	50	62.5	56.2
17.....	185	52	69	60.5
18.....	160	55.5	60	57.8
19.....	32	51	58	54.5

¹ Approximate. Counts of Dec. 8 and 15 include catch of preceding day.

Probably most of those that were caught on December 8 had migrated during the night of December 6. Not much migration from the manure takes place during the day, because of the maggots' negative reaction to light; therefore the minimum temperature is probably more significant than the daily mean temperature. It will be seen from the table that minimum temperatures of 40° F. or less will stop all migration from the heap.

It may be said, then, that the maggot trap has another defect in that it is not effective when temperatures are low, and that it is not at all effective when the air temperature is below 40° F.

SOME ADVANTAGES OF THE MAGGOT TRAP.

Some of the advantages of the maggot trap are obvious enough and need be only briefly mentioned here. It is an exceedingly simple arrangement, and the initial cost of construction need not be very great. Once having been constructed, no continuous money outlay for its maintenance is necessary. The concrete parts are permanent, and the wooden platform would require renewal only at intervals of several years, depending partly on the kind of wood used. The writer is of the opinion that in the long run the maggot trap would be less expensive than the investment which many farmers now make in screens for their dwellings and repellents, sprays, and fly nets for the protection of their animals.

The labor required in the operation of the maggot trap is a very small item. It is just as easy to place the manure on the platform as to dump it on the ordinary pile. It requires only a few minutes each day to see to it that the daily addition is carefully and compactly heaped and the entire heap well moistened. The work of cleaning out the floor below the platform will require about one-half an hour once a week.

It is very easy to run a wagon or manure spreader close alongside the maggot trap, as a glance at the photographs will show, and it would be just as easy, or indeed easier, to load from such a platform than from the ground. To facilitate loading as well as the cleaning of the floor below, the platform should be no more than 10 or 12 feet wide.

The maggot trap can be adapted for use on farms where the daily production of manure is very great. As was stated on a preceding page, the trap used in this experiment would hold the total production from three horses for three months. Now the problem of constructing a trap of reasonable size to take care of the manure of 40 or 50 horses is not as hopeless as might at first appear. The production of manure per horse per day may be safely estimated at 2 cubic feet. It will be seen that a platform 10 by 20 feet would hold manure produced by 50 horses during a period of 10 days if the heap is made 5 feet high. If two platforms are arranged as suggested in figure 4 they could be operated as follows: Platform No. 1 would be gradually filled up during the first 10 days; then, while this remains on the platform, the manure produced during the second 10 days would be placed on platform No. 2; at the end of 20 days the manure on platform No. 1 would be hauled away and the platform refilled during the third 10-day period while heap No. 2 was standing the length of time required to rid it of maggots. In this way the two piles would alternate, the one being in the process of formation and the other standing till practically all maggots had left it. It would be convenient, as indicated in

the diagram, to have a cistern located between the platforms and a pump that could be used in applying water to both piles. In making plans for a maggot trap one must take into consideration the volume of manure produced and the length of time it must remain on the platform. As previously stated, it will be safe to estimate that the production of manure per horse per day is 2 cubic feet and that after 10 days it will be practically free from maggots, provided it has been well watered.

THE INFLUENCE OF THE MAGGOT TRAP ON THE VALUE OF THE MANURE.

Plate III illustrates an all-too-common method of keeping manure. It covers a large area of ground, and no attempt at heaping has been made. The manure in such a pile is loose and shallow, and air penetrates into practically all parts. These are the conditions

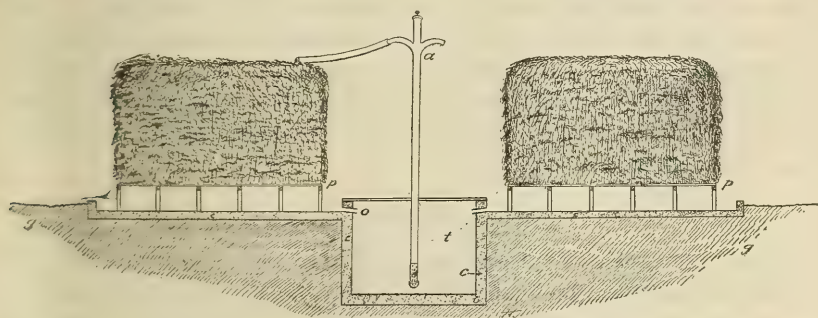


FIG. 4.—Imaginary cross-section of an arrangement suggested for use where manure production is large. a, Pump; c, concrete floor and walls of cistern; o, outlet pipes leading from floor of maggot trap to cistern; p, platform maggot trap; t, cistern for liquid manure; g, ground level. (Original.)

which give rise to the maximum loss of ammonia and nitrogen. It also happens that the conditions which tend to the loss of nitrogen are the same which favor the development of fly larvæ. An immense surface is exposed for deposition of eggs, and the penetration of air makes it possible for larvæ to feed in practically all parts. The fresher portion of the manure shown in this photograph was found heavily infested all through the season.

It has been shown that the losses occurring in manure thus carelessly stored will vary from 30 to 64 per cent of the total amount of nitrogen (Beal, 1906), and that by careful methods of storage this loss may be reduced to 15 per cent. Several methods of storage for the purpose of preventing loss of ammonia and nitrogen have been proposed. Among others is that recommended by Dehérain, Beal, Thorne, Ringelmann, and others, which consists in keeping the manure compactly heaped and well watered. Both heaping and watering tend to prevent the penetration of air and thus check the destructive

aerobic fermentation. This method is used to a considerable extent in parts of France and Germany and is fully discussed by Ringelmann. A cistern is provided into which drain all the liquids from the stables, and the manure heap is watered by pumping the liquid manure from the cistern from time to time.

It is the writer's intention here merely to point out that the disposal of manure on the platform maggot trap is but a slight modification of the method just mentioned. Figure 4 differs from a diagram given by Ringelmann only in the platform and in the outlets through which the drowned larvæ may be washed into the cistern. Here is shown the cistern in which the liquid manure collects. Watering with the liquid manure adds to the heap the valuable constituents of the urine and promotes the anaerobic fermentation. If it is true, as just suggested, that lack of oxygen and the presence of carbon dioxid render the manure unfavorable for the development of the larvæ, it follows that compact heaping and watering, by excluding air and increasing the moisture content, also insure the greatest percentage of migration. As a matter of fact, compactness and high moisture content are the very factors which make the maggot trap most effective, whether the explanation is to be found in the temperature, or moisture, or lack of oxygen.

CONCLUSIONS.

In this paper we have described the structure of, and the method adopted in using, a platform maggot trap. All the manure from a stable in which three horses were kept was stored on this platform. The results obtained during August and September seemed to show that at least 98 per cent of the larvæ breeding in this manure were destroyed. Fly counts made before and after the trap was installed indicated an average reduction of from 67 to 76 per cent. That the reduction of flies did not correspond to the percentage of larvæ destroyed was probably due to the presence of several other breeding places well within the range of flight.

Two difficulties were experienced in the practical working of the trap, viz, the accumulation of a certain amount of straw and débris on the floor under the platform and the breeding of mosquitoes in the water used to drown the fly larvæ. It was also found that low air temperatures hinder migration and consequently decrease the efficiency of the trap.

Among the merits of the maggot trap were mentioned (1) the comparatively small initial cost and absence of money outlay necessary for its maintenance, (2) the very small amount of additional time or labor required in its operation, (3) the ease with which wagons or manure spreaders can be loaded from the platform, and (4) its adaptability for use at stables where the daily production of manure

is large. Finally, it is suggested that the same conditions which render the trap most effective are the ones which tend to preserve the value of the manure.

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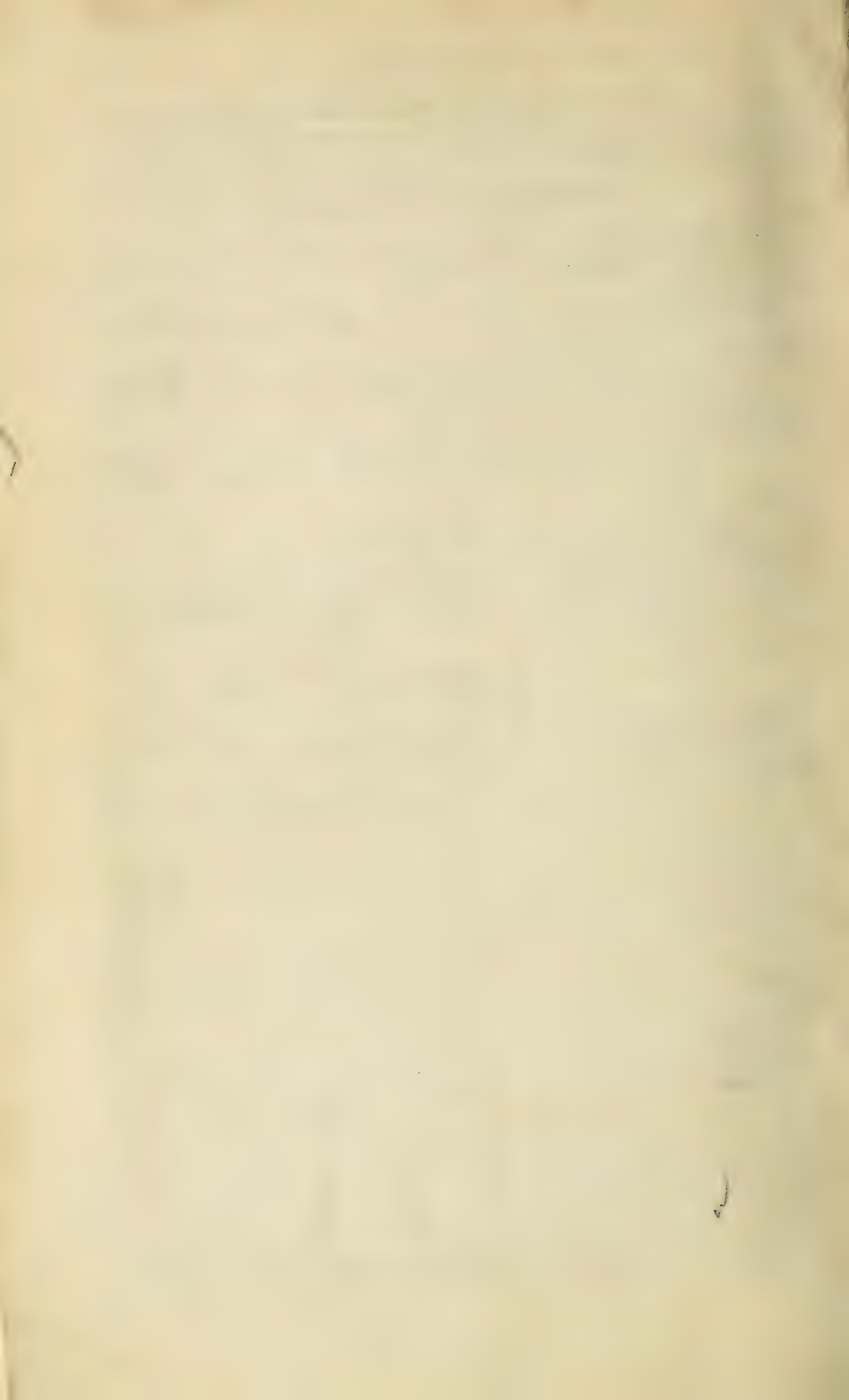
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